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FEASIBILITY STUDY FOR A DUAL FIELD OF VIEW-SINGLE DETECTOR ARRAY INFRARED SYSTEM

KAISER AEROSPACE AND ELECTRONICS CORPORATION

PREPARED FOR

ARMY ELECTRONICS COMMAND

JUNE 1974

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FEASIBILITY STUDY FOR A DUAL FIELD OF VIEW—SINGLE DETECTOR ARRAY INFRARED SYSTEM

FINAL REPORT

PREPARED BY
KAISER AEROSPACE & ELECTRONICS
PALO ALTO, CALIFORNIA

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FOR

U.S. ARMY ELECTRONICS COMMAND
NIGHT VISION LABORATORY
FORT BELVOIR, VIRGINIA
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SUMMARY

An analytical study was conducted to determine the feasibility of multiplexing two infrared images, gathered by two separate lens systems, at a coincident focal plane thereby permitting utilization of only one infrared detector array for "time shared" processing of both images.

The study was primarily directed towards determining the feasibility and practicality of:-

1.) Dual Image Opto-Mechanical Scanning techniques.

2.) Retaining flicker-free video presentations by storing and processing the multiplexed IR video.

The results of the study show that the concept is feasible and that hardware can be implemented by utilizing state-of-the-art techniques. The investigation into scanning techniques and data storage media indicates that the most suitable hardware implementation would consist of a "Collimated Dual Galvanometer" Optical Scanner and a Storage Refresh Memory utilizing MOS Shift Registers.

The determination of the practicality of a multiplexed Dual Image IR system over that of two independent IR systems is more difficult to assess. It is very probable that the weight, size and power requirements of a Multiplexed IR System will be considerably less than those of two independent IR systems; however, to determine the cost effectiveness of such a system and to arrive at a true performance comparison between a conventional and a multiplexed IR system requires a more extensive analysis based on the actual, detailed design of a specific system.

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F O R E W O R D

This report presents work performed under Contract No. DAAK02-72-C-0419 for the U.S. Army Electronics Command Night Vision Laboratory, Fort Belvoir, Virginia.

The Program objective is to develop in one optically and electronically multiplexed Infrared Display System the performance capabilities of two separate IR Display Systems.

INTRODUCTION

The objective of this study is to determine the feasibility of multiplexing two infrared images, gathered by two separate lens systems, at a coincident focal plane thereby permitting utilization of only one infrared detector array for processing and displaying two different fields of view simultaneously on two display monitors.

A further aim of the study is to investigate the performance tradeoffs associated with such a multiplexing scheme in order to define realistic hardware parameters for the development of a multiplexed system.

The need for a study to investigate the feasibility of multiplexing two infrared images on one detector array arises from the fact that present day real time IR Display Systems do not employ detector-time share techniques to obtain maximum system versatility.

A typical passive IR display system for example, consists of the following major building blocks:

1. Lens system
2. Optical Scanner
3. Detector Array and associated cryogenic cooling system
4. Preamplifier and sync circuits
5. Video Monitor

In an airborne application, such a system can present information for navigation, target search, weapon delivery, etc. By providing gimbaled, variable field of view optics and multi-station video monitors, the pilot, navigator and gunner can each view information necessary for their particular need. However, they cannot do this simultaneously. In other words, if the pilot requires a wide angle, fixed field of view display for navigation or target search while simultaneously the gunner is trying to track or identify a target with a gimbaled telephoto field of view, one or the other function has to take precedence unless two complete IR systems can be provided.

Since the detector array, preamplifier and cryogenic cooling unit represent a major cost and weight factor of an IR video display system, it would appear advantageous to time share these elements instead of providing two complete systems. This study will try to determine the advantages or disadvantages of a time sharing scheme.

DISCUSSION

1.0 GENERAL CONSIDERATIONS

The investigation of the feasibility of multiplexing two infrared images through a single detector array falls into two separate, yet related, areas. The first area of investigation is the determination of the opto-mechanical requirements for irradiating one detector array with two images. The second area requiring investigation is the electronic processing of the two optically multiplexed images. At first glance, neither area appears to present any particular problems. To scan two separate images past a detector array certainly is not difficult and can be done with a rotating or oscillating mirror. Separating and extracting the two images from the detector output and channeling each image to a separate viewing monitor also presents no particular challenge to the present state-of-the-art.

Why proceed then? Well, the previous statements are only true provided the system performance is independent of optical and electronic scan efficiency. If, for example, the existing display output is in the form of a raster display with a 60 Hz frame rate and if it is found that a 30Hz frame rate provides equivalent performance in regard to brightness, absence of flicker and smear, resolution and viewability, then it follows that two different display fields could readily be multiplexed through the existing electronics at a 30 Hz frame rate per display. A similar comparison can be drawn for the detector scan efficiency. For example, if in the existing display system the IR detectors are only irradiated 50% of the time, then a relatively simple opto-mechanical device, such as a flip mirror, could be used to direct the second image to the detectors during the remaining 50% time period. In actuality, however, system performance is a direct function of opto-mechanical and electronic scan efficiency.

The underlying premise for this study then is to investigate dual field multiplexing schemes which retain present single field system performance or, at least minimize the extent of performance degradation due to time sharing.

The following paragraphs will address first the optical and then the electronic multiplexing possibilities.

2.0 DUAL INFRARED IMAGE OPTO-MECHANICAL SCANNING

2.1 Introduction

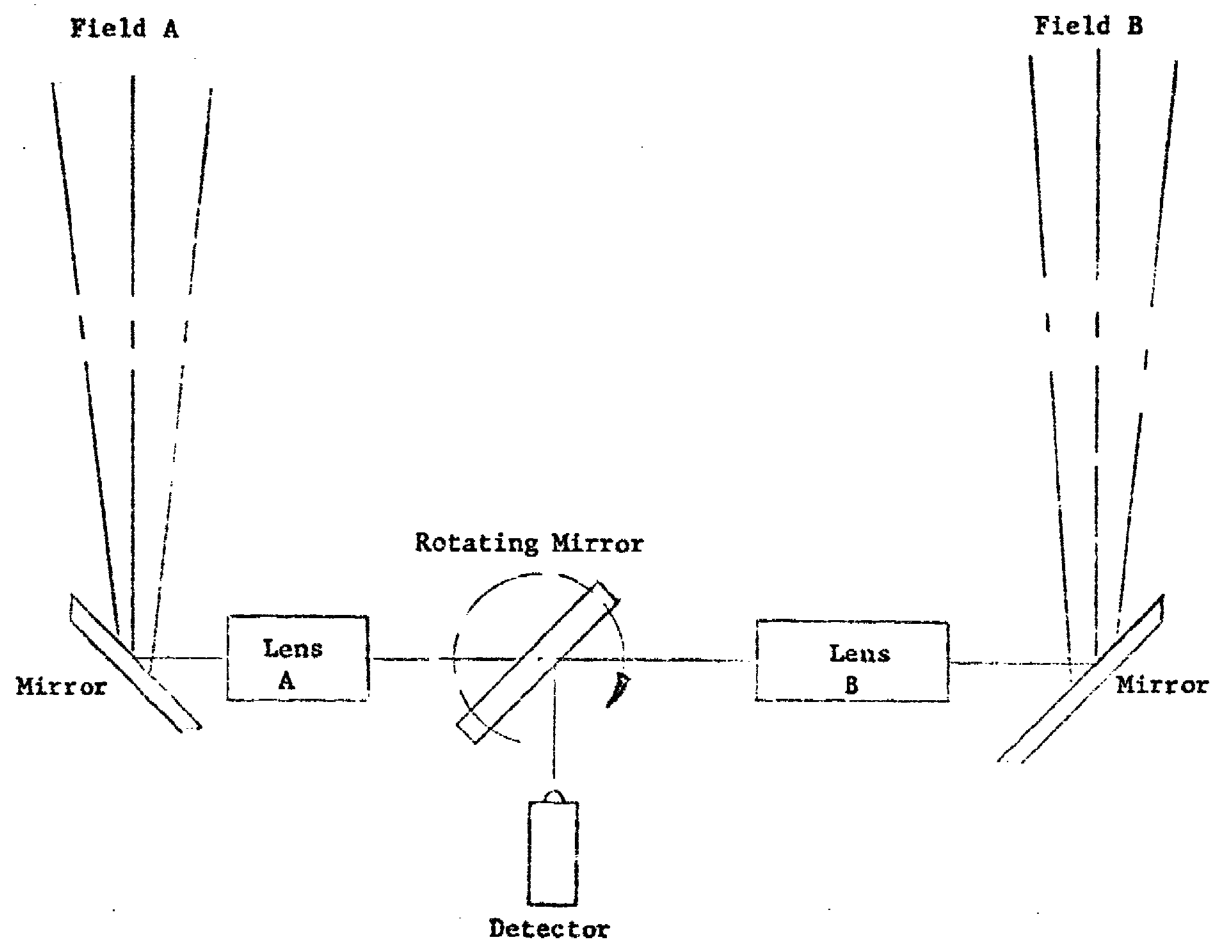
A majority of present day Infrared Display Systems require an opto-mechanical scanner to direct the viewed scene to the IR detectors. A wide variety of scan mechanisms have been devised and are in use today. The increased performance capability of present day IR display systems is the result of improvements in all functions in the IR system chain. New optical materials in conjunction with new highly efficient IR coatings have resulted in more transmittant lens systems; detector sensitivities and resolution have increased; and, coupled with improvements in detector signal processing, have brought about IR display systems of impressive image quality. These advances in the Infrared Display Field have necessitated the development of opto-mechanical scanners of high efficiency and precision. Scan efficiencies of nearly 100% are now being achieved.

Several scanning methods were investigated for their adaptability to Dual Image Scanning. The following paragraphs describe the results obtained.

2.2 ROTATING MIRROR SCANNER

The most basic scanning technique is shown in Figure 2-1. In the position shown, lens A is imaged onto the detector array. After the mirror rotates 90 degrees, lens B will be imaged onto the detector. Assuming for the moment that both lenses have a 5° field of view and present a 1" x 1" aerial image at the detector, it then follows that a 2.5° mirror rotation is required to scan one total field. Since the mirror rotates through 360° for both image scans, the scan efficiency for both fields is:

$$S_{EFF} = \frac{2 \times 2.5^{\circ}}{360} \times 100\% = 1.4\%$$



Rotating Mirror Scanner

Figure 2-1

Correspondingly, a 60° field of view for both lenses would result in a total scan efficiency of:

$$S_{EFF} = \frac{2 \times 30^{\circ}}{360^{\circ}} \times 100\% = 17\%$$

Aluminizing both surfaces of the mirror doubles this efficiency.

In a situation which requires scanning a 5° and 60° FOV a double-sided mirror gives the following scan efficiencies:

$$S_{EFF}\ (5^{\circ}) = \frac{2(2.5^{\circ})}{360^{\circ}} \times 100\% = 1.4\%$$

$$S_{EFF}(60^{\circ}) = \frac{2(30^{\circ})}{360^{\circ}} \times 100\% = 17\%$$

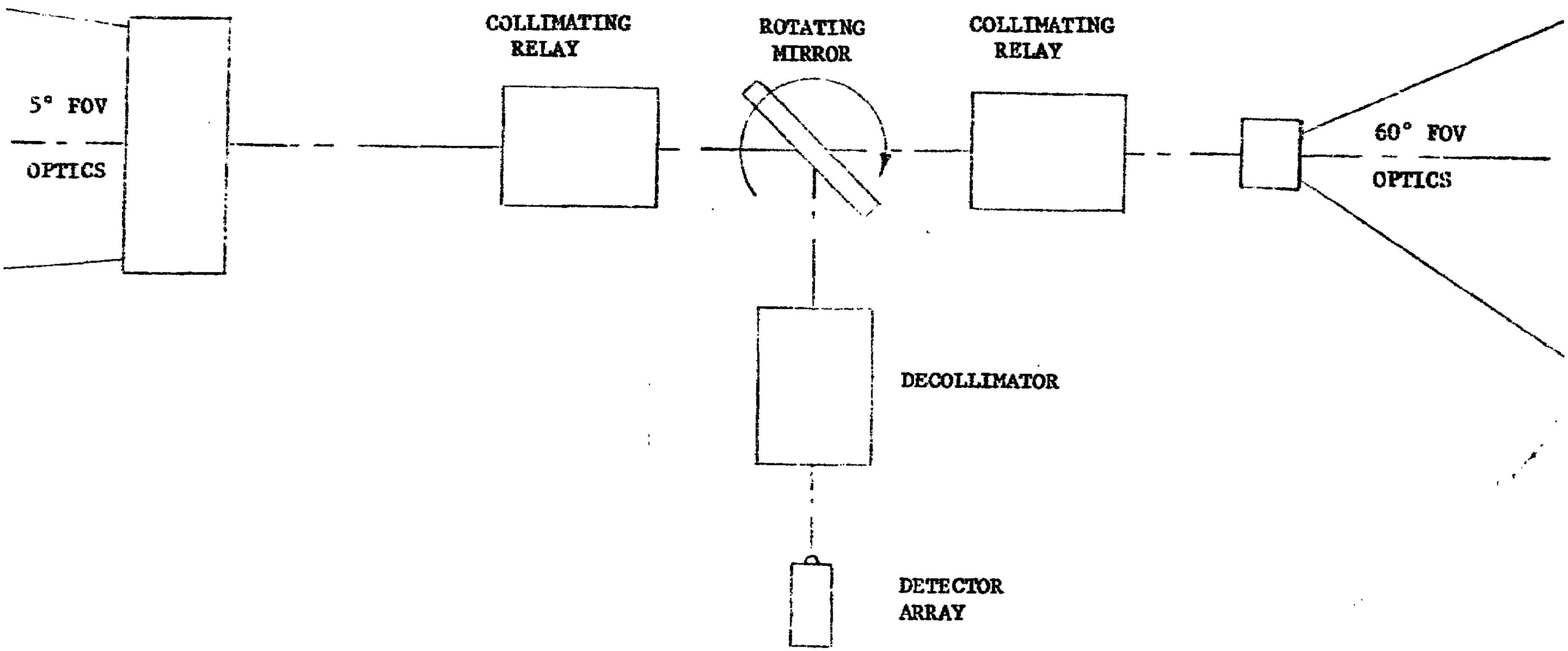
These efficiencies are far below the theoretically possible 50%, especially for the 5° FOV.

Considerable improvement in scan efficiency can be achieved by making the mirror velocity variable such that the 5° field is scanned at a slower speed to correspond to the scan efficiency of the 60° field. By this method the detector dwell time per unit image area can be equalized for both fields; in other words, the scan efficiency for both fields could be increased to 17% per field.

Even though this is technically feasible, the mechanical complexity required to achieve scanning linearity is undesirable and costly.

2.3 COLLIMATED BEAM ROTATING MIRROR SCANNER

The complexity of a variable speed scanner can be eliminated by a collimated beam scanner (Figure 2-2). In this arrangement both the 5° and 60° fields are focused into equivalent sized images. Each image is then collimated and scanned by the rotating mirror. The scanned image is then decollimated and focused on



DUAL CHANNEL COLLIMATED BEAM SCANNER

Figure 2-2

the detector array. Since both images seen by the mirror are of equivalent angular subtent, the mirror velocity can be constant for equivalent scan efficiency per image.

Assuming a collimated 60° FOV for each image, the scan duty cycle would be 17% per image instead of 17% and 1.4% for the convergent beam scanner.

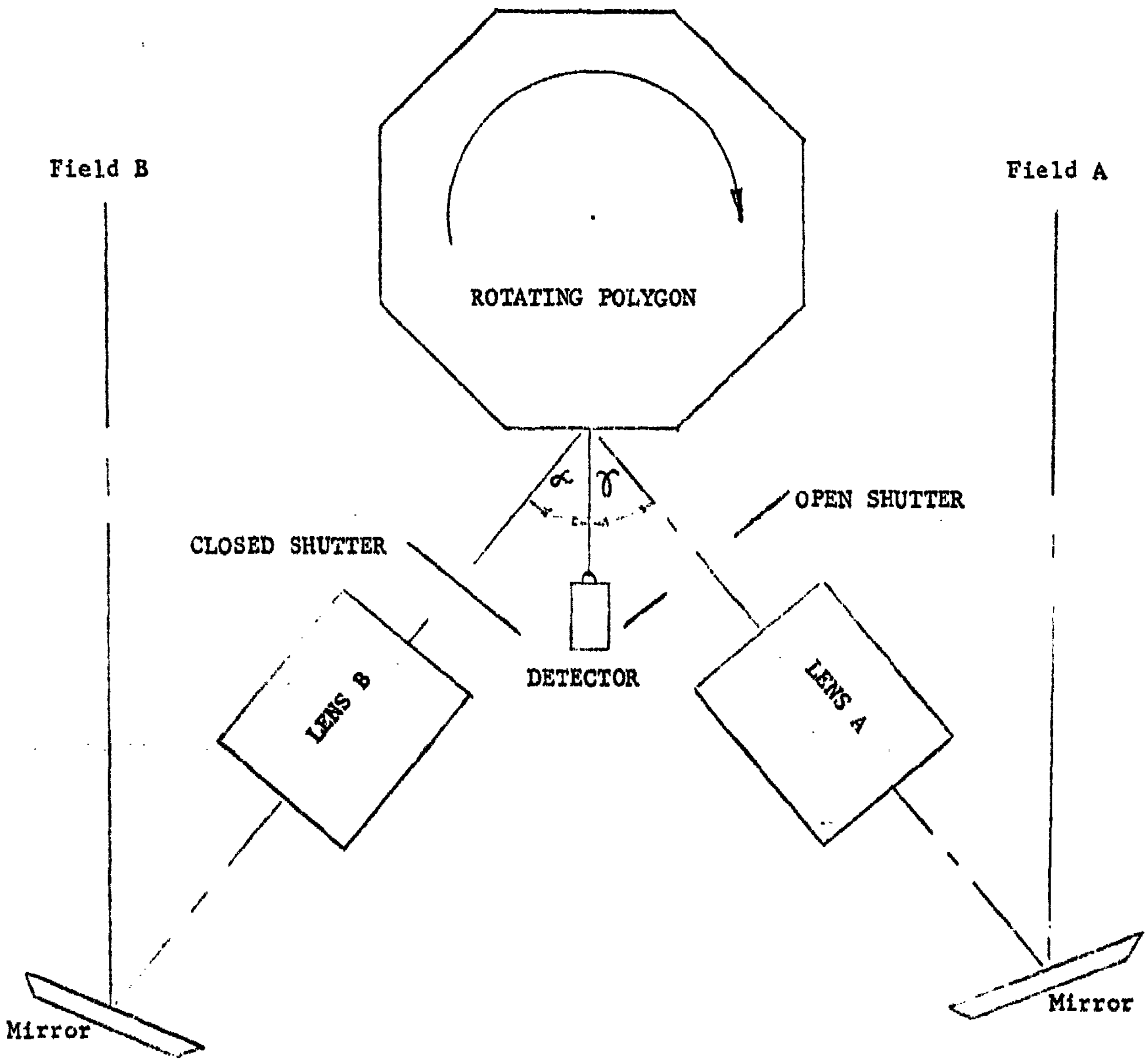
Even though this technique equalizes the duty cycles of the two images, the total duty cycle is still very low.

2.4 ROTATING POLYGON SCANNER

A rotating polygon system is shown in Figure 2-3. If the polygon has N faces and provided the face width is sufficiently large to cover both fields of view and the angular separation of the two fields, then an angular rotation of $\frac{360}{N}$ degrees will reflect both fields across the detector.

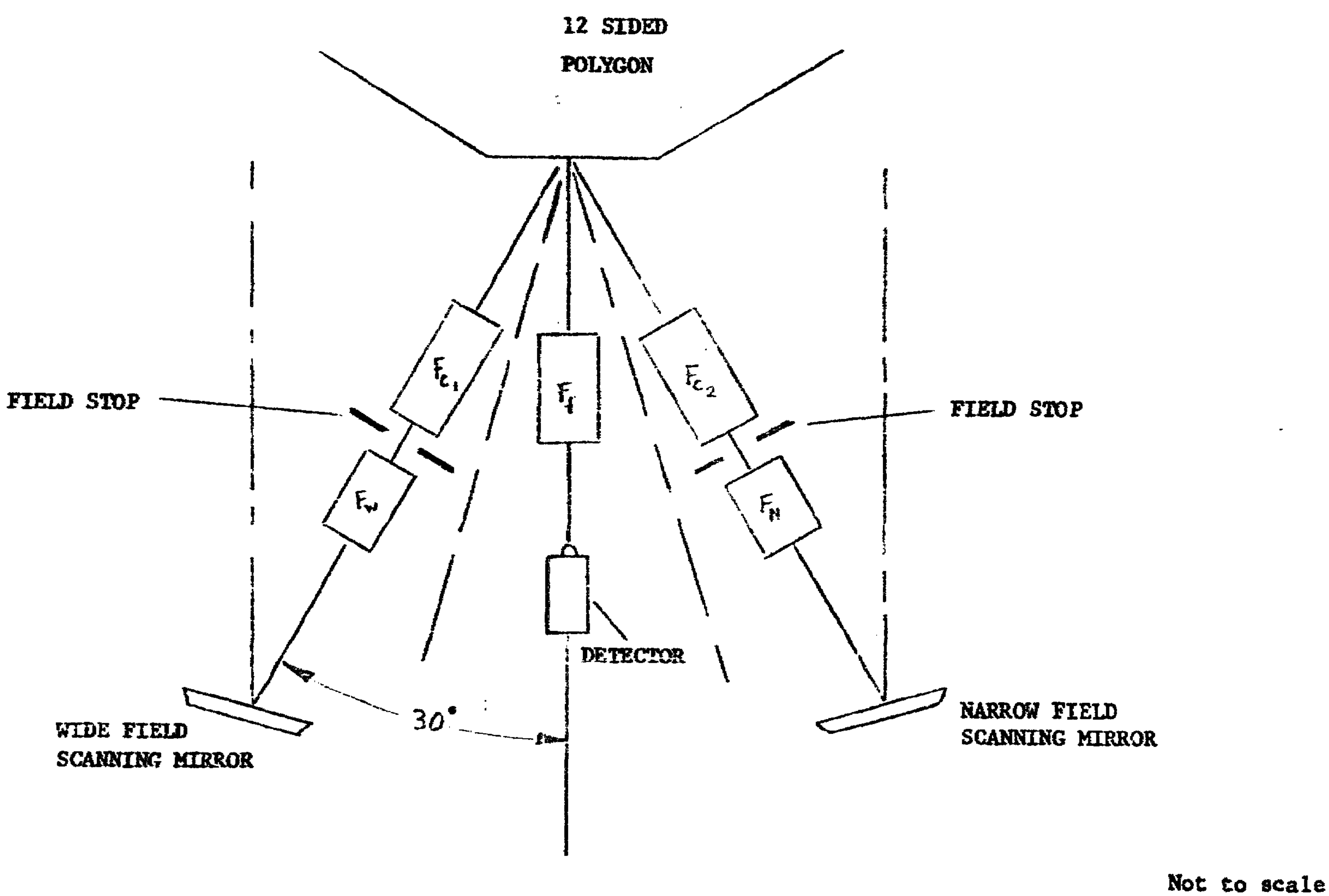
The scan efficiency of such a system is a function of N (number of polygon faces), the angular separation between the two fields of view ($\alpha+\gamma$) and the field angles of the two lenses A and B. The angular image separation $\alpha+\gamma$ ideally should be 0° in order to achieve a high scan efficiency (i.e., the two fields are adjacent to each other); however, physical constraints such as required lens aperature sizes, polygon diameter and path length from lens to mirror to detector (lens focal length) make the angular field separation equivalent to or larger than, the sum of the half field angles of lenses A and B. The practical aspects and constraints of this system result in only a moderate scan efficiency increase over that of the previously discussed rotating mirror scanner.

A further disadvantage of the polygon scanner is the requirement to prevent energy from both fields of view to reach the detector simultaneously. This can be done by shutters which are activated by the polygon rotation mechanism; however, this requires a complex mechanism. Also, since the images are directly



POLYGON SCANNING SYSTEM

Figure 2-3



COLLIMATED POLYGON SCANNER

Figure 2-4

focused unto the detector array, the spacings between lens, polygon face and detector must be very precise. The requirement for precise spacing can be somewhat alleviated by a Collimated Polygon Scanner as shown in Figure 2-4. In this system the two images are not directly scanned, but instead each field is imaged at an intermediate plane, collimated by lenses F_{c1} and F_{c2}, scanned and decollimated and focused by lens F_f unto the detector array. In the collimated section of this system the optical element spacing tolerances can be relatively large. An additional advantage arises from the fact that in the collimated polygon scanner the final image at the detector is in focus over the whole field whereas in the previously mentioned uncollimated polygon scanner the linear image is scanned past the detector on an arc, which requires that the optics have a sufficient depth of field so that the image stays in focus at the detector plane.

The scan efficiency, however, of either the collimated or uncollimated polygon scanner is nearly equivalent; i.e., relatively poor.

2.5 OSCILLATING MIRROR SCANNER

It is possible to make an oscillating mirror system which is nearly 100% efficient. A schematic for a Dual Field Scanner employing an oscillating mirror is shown in Figure 2-5. In this design, lenses A and B are separated by an angle 2 Ø. The mirror shown in front of lens A is used to make the line of sight of both lenses parallel. If lens A is the long focal length lens (narrow field), this mirror may be used to select a specified target area.

Assuming that both lenses A and B present aerial images of equivalent size, the detector is located such that at mirror position 3 the end of field A and the start of field B are imaged on the detector. At mirror position 4 the center of field A is imaged on the detector and correspondingly at mirror position 2 the center of field B is imaged on the detector. Mirror positions 1 and 5 image the extreme edges of the two adjacent fields onto the detector. By limiting the mirror oscillation to positions 1 and 5 a high scan efficiency can be achieved; however, this system exhibits several undesirable features:

1. Normally a lens has a real field of view greater than its design field. That is, if a lens has a 30 degree design field, energy will pass through the system and form a low quality image at, say, 40°. This will result in "cross-talk" in this type of scanning system unless a field stop is introduced at an intermediate image which then requires an additional relay lens. Figure 2-6 shows such a system for a 5° FOV, F/4 optics for a 1 inch long detector array. The aperture stop for this configuration must also be a cold stop which is undesirable from a thermal load viewpoint.

2. The detector must have a large acceptance angle to accept the beam at mirror positions 1 and 5.

3. The oscillating mirror has to be very large to scan both fields of view.

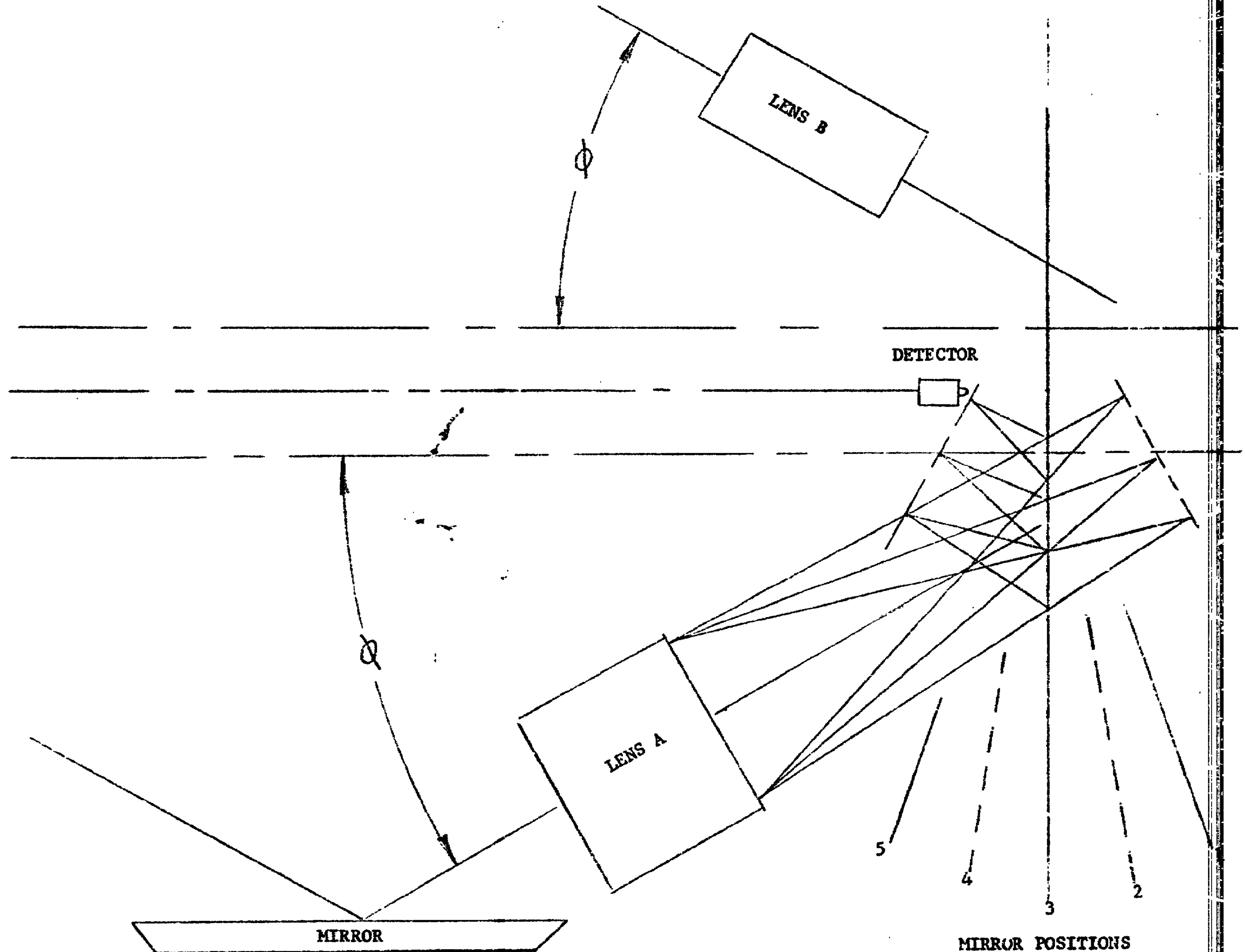
4. The major drawback of this system is shown in Figure 2-7 which **shows an enlarged view of the oscillating mirror optics.** For simplicity, only one half of the system is shown with only the principal rays going to three image points. In order for the image to remain on the detector as the mirror moves, the following conditions must exist:

$$L_1 = L_1^{1} \qquad \theta_1 = \theta_1^{1}$$

$$L_2 = L_2^{1} \qquad \theta_2 = \theta_2^{1}$$

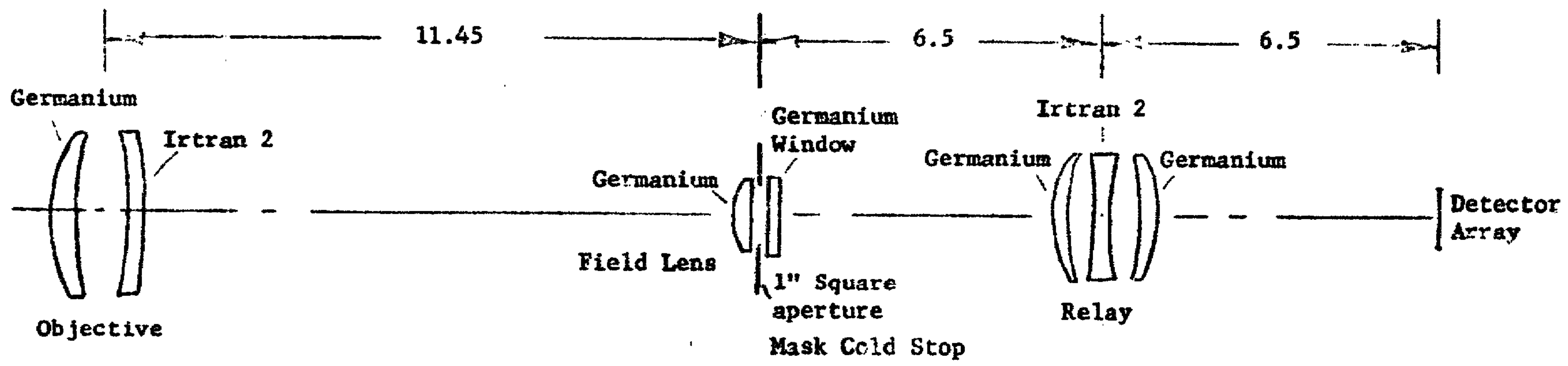
$$L_3 = L_3 \qquad \theta_3 = \theta_3$$

It is obvious that this cannot be achieved by oscillation about a single axis but requires a complex simultaneous translation of the oscillation axis.



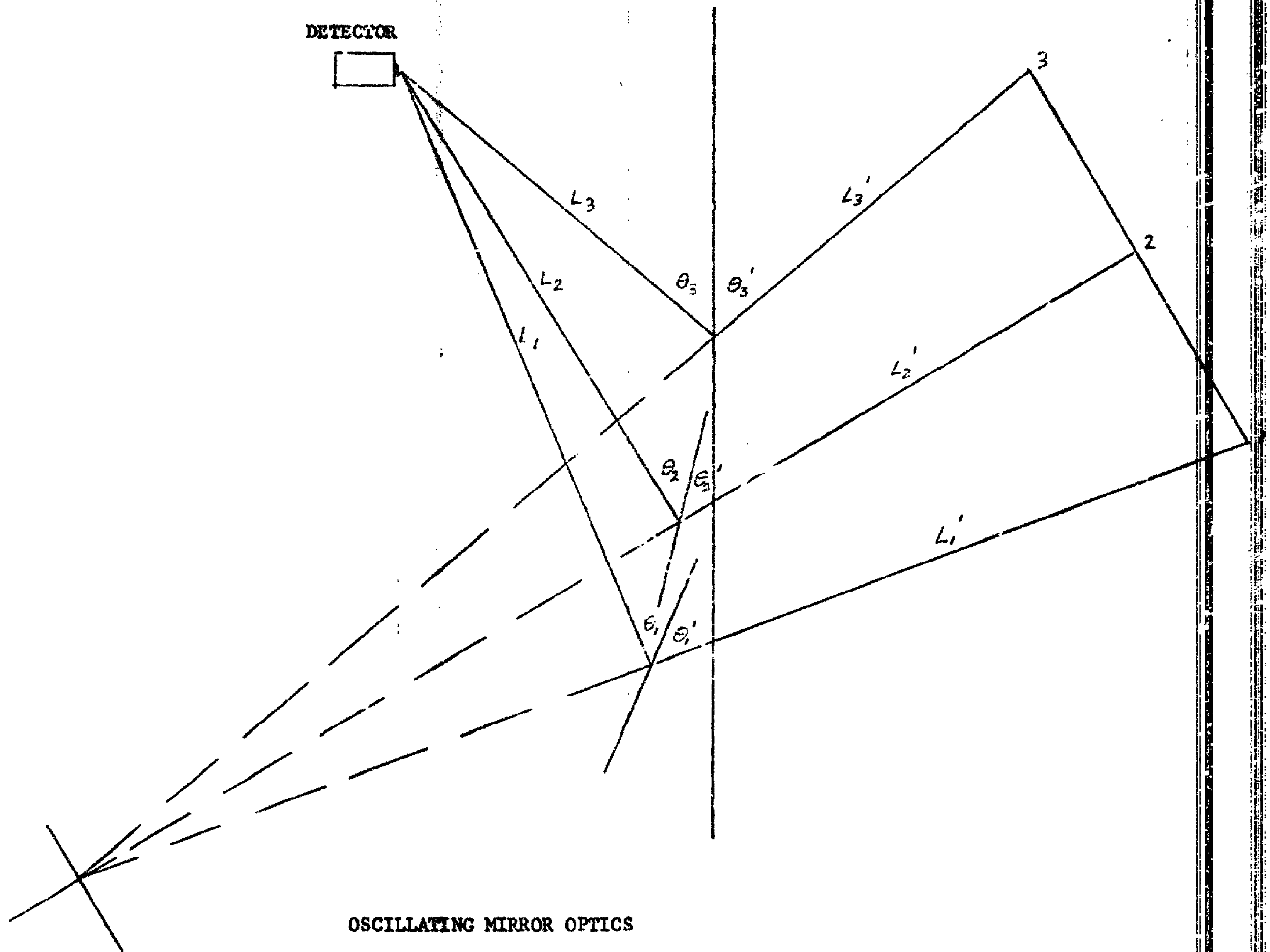
OSCILLATING MIRROR SCANNER

Figure 2-5



LENS A 5 DEGREE, F/4 OPTICS

Figure 2-6



OSCILLATING MIRROR OPTICS

Figure 2-7

2.6 CYLINDRICAL MIRROR SCANNER

A system which eliminates the need to cold stop the background is shown in Figure 2-8. In this system the field stop is scanned with a vertical slit and essentially all the energy falling on the cylindrical mirror will be focused as a vertical line on the detector array.

Several of the previous problems have been solved in this system. The detector is never exposed to background radiation and scattered radiation from mirror edges has been eliminated.

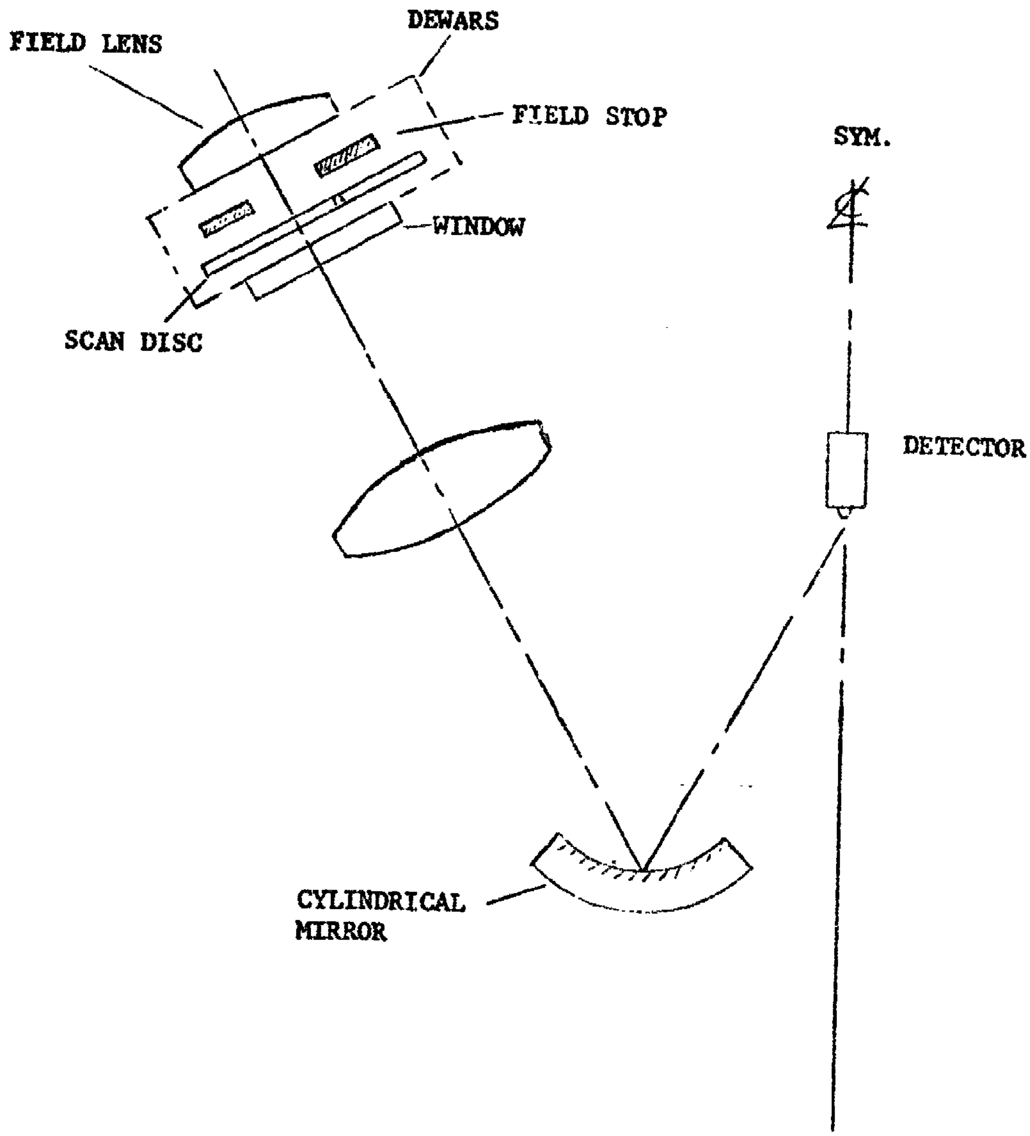
This system requires that the two scan disc motors for the wide and narrow field of view be slewed together to allow the detector array to "read" each view alternately. This system would very closely approach the ideal 50-50 scan duty cycle. Synchronizing the rotating scanning discs is well within the present technology. Since the discs would most likely be very thin, it is quite likely that only static balancing would be required.

The serious drawback of this system is the fact that the scanning disc must be cold stopped. Besides being cold stopped, it must be of uniform temperature to avoid a modulated background signal. The disc must therefore be mounted on the cold finger in the vacuum of the dewar. Aside from placing a large thermal load on the dewar, heat transfer to the rotating disc in absence of air will be very poor. Lubrication of the bearings in the vacuum without fogging the windows presents an additional problem.

The practicality of this system is questionable.

2.7 "ADJACENT FIELD" SCANNER

In the system shown in Figure 2-9, the basic approach taken was to evaluate scanning two fields adjacent to one another. The two fields must be optically adjacent and must be near the same size in order to reduce "dead time" losses.



CYLINDRICAL MIRROR SCANNER

Figure 2-8

Both fields are crossed during each scan. Obtaining the appropriate field size is accomplished in the example by selecting objectives with the proper focal lengths.

Two scanning techniques have been evaluated, an oscillating mirror scanner and a rotating mirror scanner. Both scanners use the same optical configuration which consists of narrow field, L1 and wide field, L4 objective lenses, a relay lens, L2 for the narrow field side and a very wide field autocollimating scanner objective, L3. Auxillary lenses and windows associated with the detector arrays were not considered at this time, but may be included in the design as required. Gimballed mirrors may also be used to steer the optical beams.

Based on the requirement of 0.2 degree Kelvin system sensitivity, the following aperture requirements have been estimated:

Detectors	Entrance Pupil Diameter	
	5 Degree FOV	60 Degree FOV
352	4.0 inches	1/3 inch
176	4.8 inches	.4 inch
88	6.8 inches	.56 inch

The above figures show the tradeoff between a number of detectors and the size of the optics.

It will be assumed that an array of 88 detectors will be scanned with a 4 to 1 interlace. The scan efficiency of either an oscillating mirror scanner or a rotating mirror scanner is nearly equivalent in this application. However, the oscillating mirror scanner requires a more complex drive mechanism, particularly for interlace.

Using the above values in the optical scheme shown in Figure 2-9, it is estimated that a one inch diameter scan mirror must scan through a mechanical angle of 30 degrees. Data sheets on General Scanning Incorporated devices indicate that such performance is possible using ramp drivers at frequencies in the neighborhood of 60 hertz.

A multiface rotating mirror can be substituted for the oscillating mirror as shown in Figure 2-9. A twelve sided mirror would provide 30 degrees of mechanical rotation per optical face. The principal advantage of this approach over the oscillating mirror approach is that it provides a convenient way of introducing interlace. The principal disadvantage is related to the sensitivity, in that the detector must continuously receive unwanted background radiation.

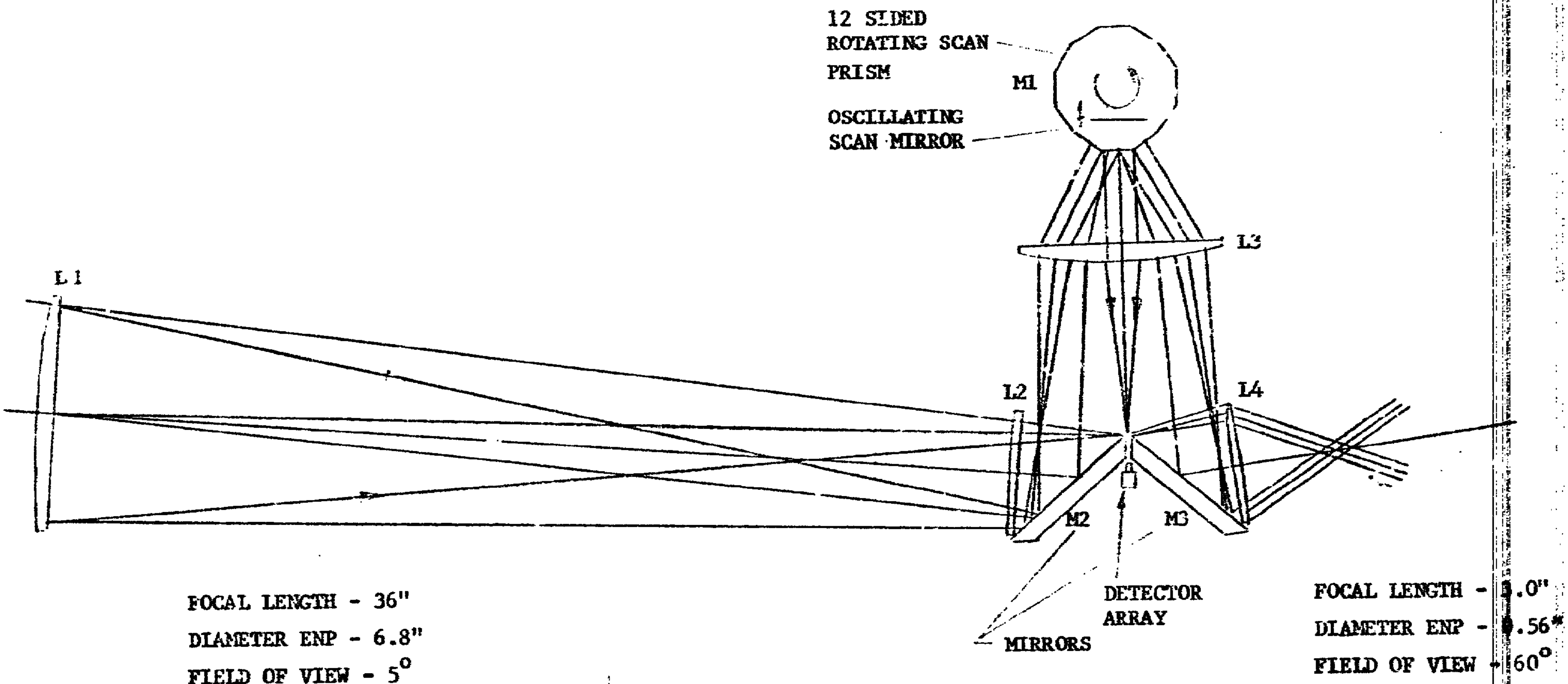
The Scan Duty Cycle with either approach is expected to be between 40% to 45% per image.

Video and horizontal sweep signals required for the two displays are shown schematically in Figure 2-10. A cold spike is generated as the scanner scans the image of the detector across itself. This may provide the timing information for the display.

The optical system has been kept as simple as possible in order to reduce weight, costs, and transmission loss. The narrow field objective is an F/5.3 singlet. Germanium was selected as the optical material because of its excellent transmission properties, low dispersion, and relatively low cost.

By using antireflection coatings the transmission of the elements should be approximately 95% per element. With six or seven elements in the optical train transmissions will be approximately 70% to 73% including dewar window losses. If losses could be held to 97% per element, 89% overall transmission could be attained.

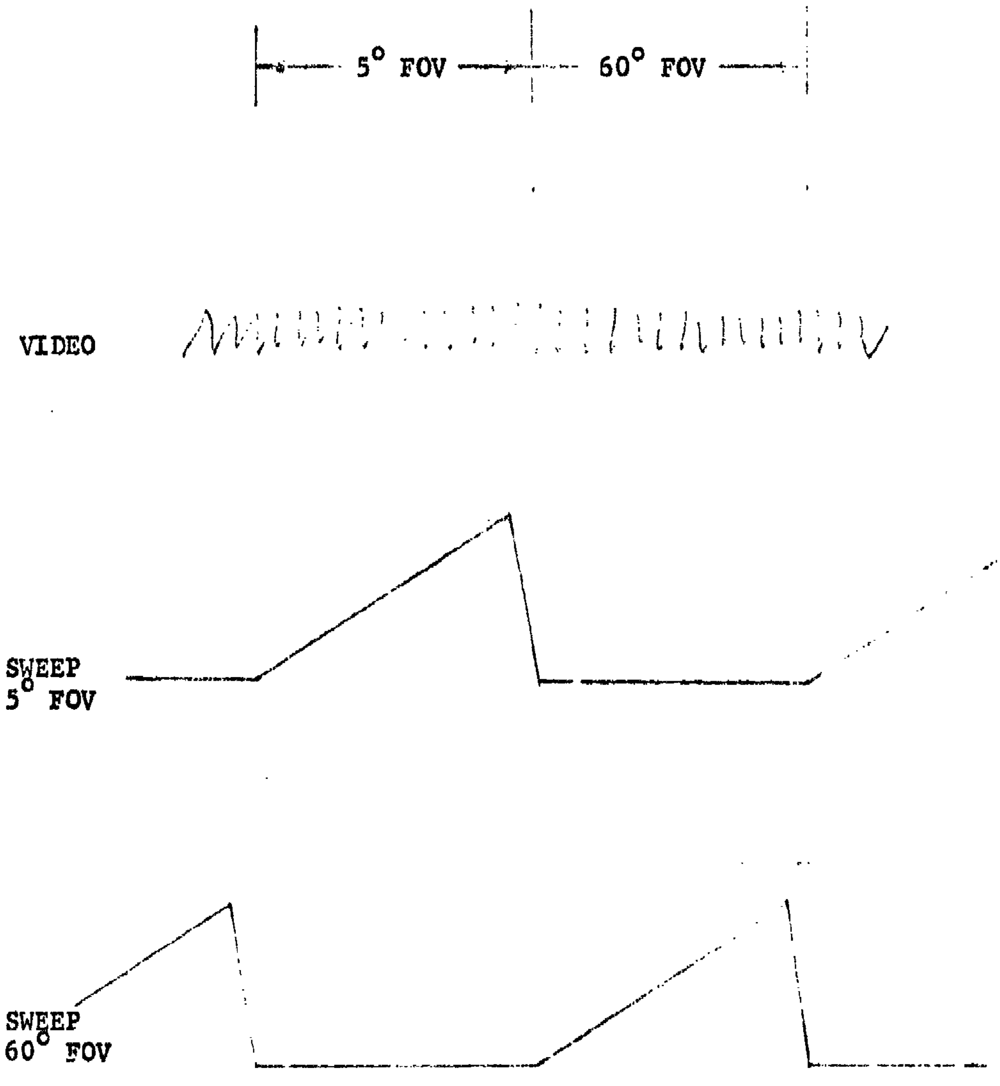
The scanner lens is limited in performance by curvature of field. The narrow



"ADJACENT FIELD" SCANNER

Figure 2-9

Scale ≈ 5:1



VIDEO AND SWEEP SIGNALS

Figure 2-10

field objective is limited in performance by spherical aberration and astigmatism and the wide field objective is limited by spherical aberration, astigmatism, and curvature of field. However, the overall system performance is near the required performance.

Modulation at a spatial frequency of the 176 cycles per frame due to the spatial integration effects of the detector and diffraction effects is approximately 48%. From the third order analysis of the optical components the modulation of the optical system at 176 cycles per frame is as follows:

Sub System	Modulation Due to Third Order Aberration Effects	
	On Axis	Edge of Field
Narrow Field of View	75%	5%
Wide Field of View	85%	5%
	Modulation Due to Diffraction, Third Order Aberration and Detector	
Narrow Field of View	35%	2.5%
Wide Field of View	40%	2.5%

These values are below the target value of 50%. A detailed optical design for a specific system should be performed in order to ascertain whether or not the required off axis resolution can be achieved, particularly in view of the rather stringent wide field optical performance requirement placed on the autocollimating scanner objective L3.

2.8 COLLIMATED DOUBLE GALVO SCANNER

A scanning system utilizing two moving-iron galvanometer scanners is shown in Figure 2-11. In this system each image is first brought to an intermediate focus at a field/cold stop, then collimated by lens F_c, galvo scanned and decollimated and focused onto the detector array by lens F_f. The two galvos alternately pass each of the images at the field stops past the detector array.

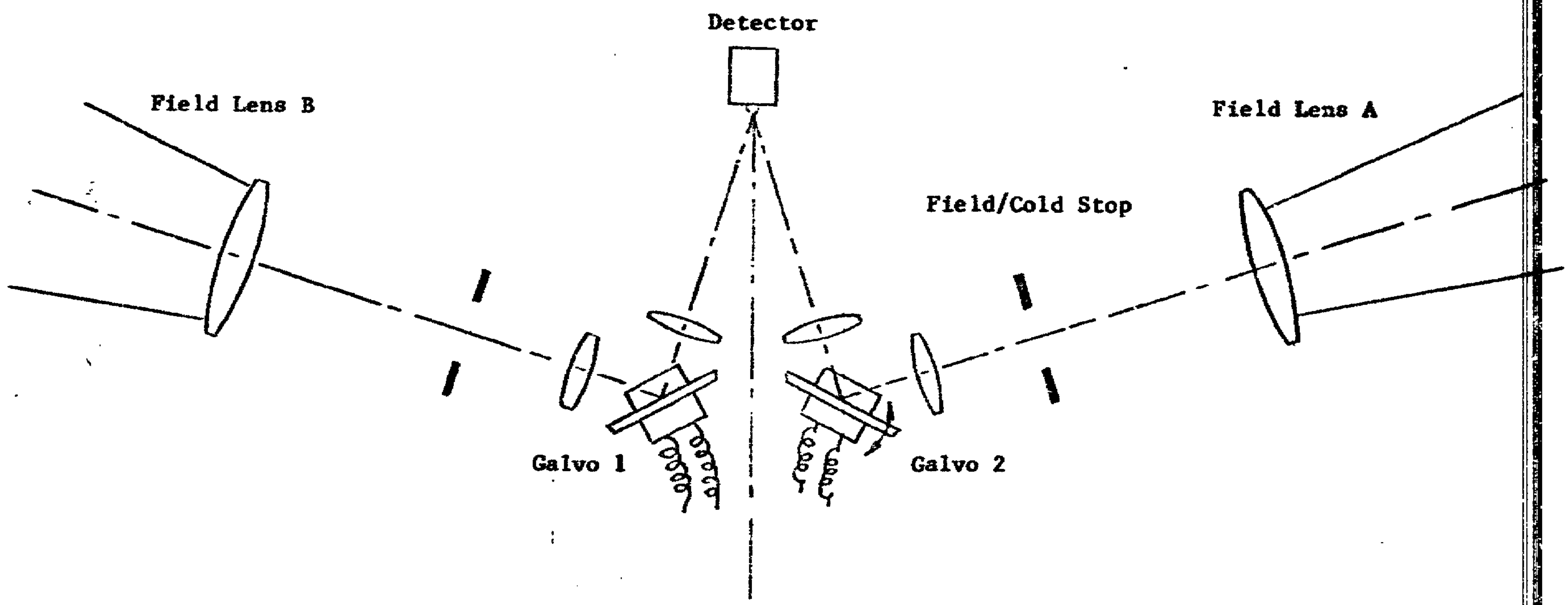
As with all galvos, they should be blanked out at the beginning and end of each swing to slow the mirror to a stop, accelerate it back up to speed in the opposite direction and allow any transients to settle down before starting the next constant speed scan. This takes time and reduces scan efficiency. But in this system we can take advantage of this "dead" time to scan the detector with the alternate image and achieve an almost 50-50 scan efficiency with a good linear scan. The requirements placed on the galvos are rather mild in this system. A high speed return or instantaneous direction reversal is unnecessary; in fact, the galvo reversal time must be equivalent to the active scan time since the active scan time of the second galvo occurs during the reversal time of the first galvo. This is illustrated in the timing diagram shown in Fugure 2-12.

The phasing of the two galvos is critical and will require that the galvos are synchronized to each other; however, the galvo technology is well developed and a system could be built with a minimum of development effort and risk using available technology.

The galvo system will require that a cold field stop of approximately twice the image diameter be provided to insure that during the overscan of G1 the detectors receive a uniform background radiation so that the "active scan" radiation from G2 is clearly discernable.

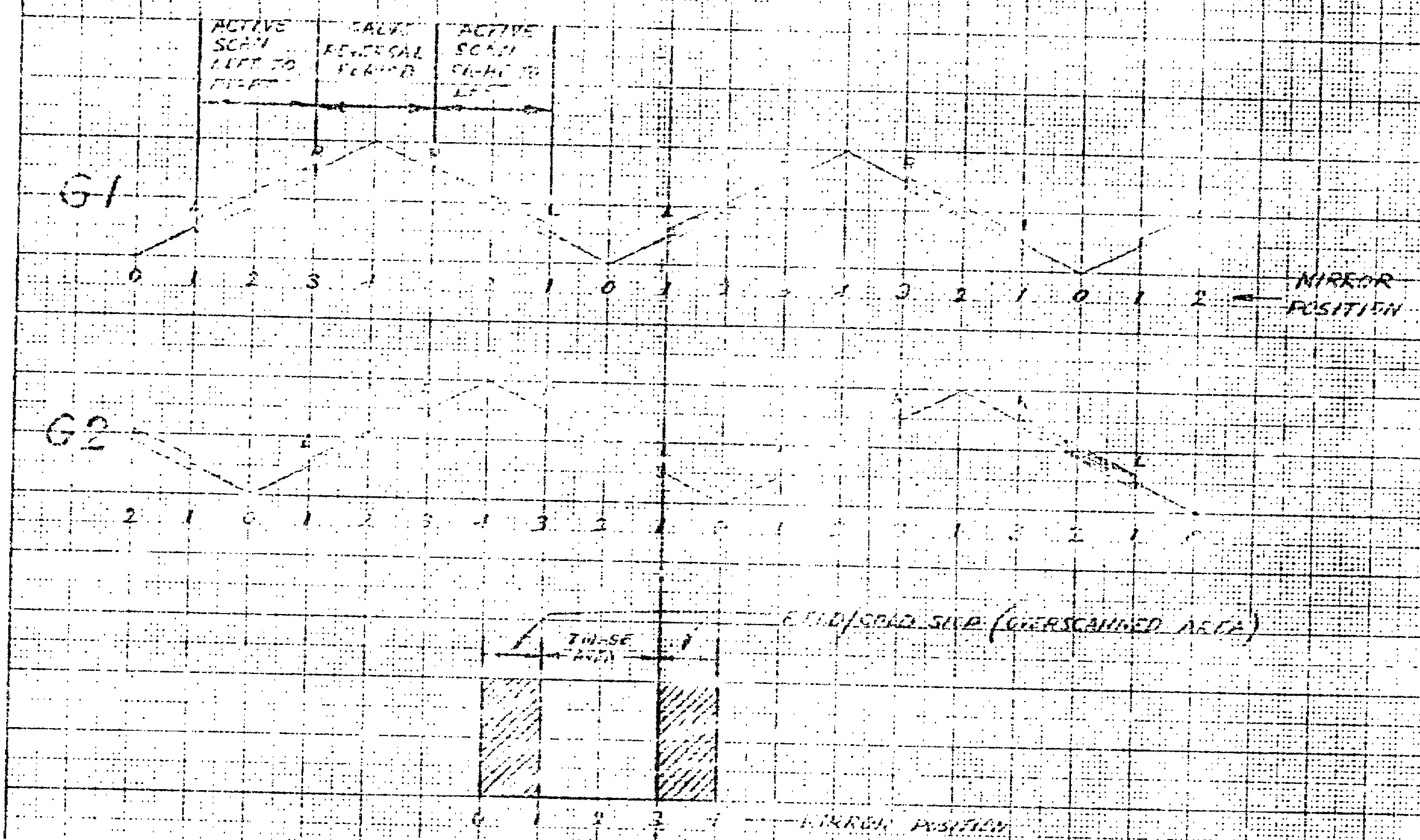
An additional requirement is that the detector acceptance angle be sufficiently large to accept the off axis irradiation inherent to this system. 2 : 1 scan interlace can be achieved in the Galvo System by either inserting a "nodding mirror" into the optical path or by utilizing an X - Y Galvo scanner with two degrees of freedom. The latter technique is less complex and appears practicable in view of the slow reversal requirement imposed on the Galvos.

In summary, the Collimated Double Galvo Scanner offers good linearity and scan efficiency coupled with low development risk.



COLLIMATED DOUBLE GALVO SCANNER

Figure 2-11



DOUBLE GALVO SCANNER TIMING DIAGRAM

Figure 2-12

2.9 SUMMARY - DUAL IMAGE SCANNER

The investigation of optomechanically multiplexing two IR images has so far shown that this is definitely feasible. Of the systems considered, the Collimated Dual Galvo Scanner appears to offer the most promise with respect to high scan efficiency and low developmental risk. Interlace is somewhat more difficult to mechanize in the Galvo Scanner than in a Polygon Scanner where the inclination of adjacent facets can be varied. The "Adjacent Field" Scanner would be the second choice for a more detailed study; however, it is felt that the optical requirements imposed on this design will result in a complex and costly system, particularly in order to achieve acceptable off axis resolution.

At this time it is difficult to present a precise, quantitative performance comparison between a Dual Image and a conventional Single Image IR Scanner.

The overall effect of the transmission losses of the additional elements (collimating lenses) and the effect of a 50% reduced scan efficiency for a Dual Image Scanner can only fully be assessed when compared to a specific system whose total performance parameters and limitations are known.

If, for example, the existing system performance is "front end" limited due to low optics transmission and slow detector response, then the additional transmission loss and halving of the scan efficiency in the Dual image mode will certainly degrade the overall display performance. On the other hand, if the system performance is limited by detector resolution or electronic signal processing, then the additional losses of a Dual Image Scanner could be of little consequence, particularly in view of the data storage and image enhancement considerations to be discussed in the following section.

3.0 DATA STORAGE TRADE OFF ANALYSIS

3.1 Introduction

This section will present trade off information and analyses in the area of the data storage function which is a primary component of the multiplexed forward-looking infrared system.

Figure 3-1 is an over-all block diagram of the Dual Channel Infra Red Multiplex System (IRMUX). As seen in this figure, and as described in Section 2 of this report, a single IR detector array is time shared between two different optical systems and an optical scanner/multiplexer. The composite video signal produced by electrically scanning of the IR detectors is an electrical analogy of the thermal image in the field of view. This signal can be processed, stored, and displayed in a standard fashion on a cathode ray tube monitor, or in the case of the Dual Channel IRMUX system, on two monitors.

The Display Processor function, including display refresh memory, is included as a primary system component to enchance display viewing by maintaining the display refresh rate above the flicker threshold. Without this memory, the refresh rate of the two multiplexed displays would be one half that of a single standard system. With the inclusion of this memory in this IRMUX system, flicker does not become objectionable in either display.

3.1.1 IRMUX Display Processor

Each of the FLIR optical multiplexing schemes described in Section 2 generates two independent optical fields of view from one IR detector array. A fundamental characteristic of these IRMUX systems is the diverse scanning techniques and frequencies that can be mechanized from the basic system concept. Kaiser has investigated the IRMUX Display Processor requirements necessary to insure compatibility between two object-space optical scans and two corresponding display-space CRT monitor formats. Figure 3-2 is the simplified block diagram of the IRMUX Display Processor. Organization into modular blocks as shown permits the expansion of display system functions when required by particular IRMUX applications.

The IRMUX Display Processor discussion that follows is predicated on general analytical considerations. It should be borne in mind that each IR detector and/or display parameter may be modified or influenced by the particular application of the dual channel multiplexed optics.

An IRMUX Display Processor provides the necessary signal processing and data memory coordinate scan conversion (if applicable), and video and sweep circuits in a format suitable for display on CRT monitors. The basic organization of the Display Processor is as shown in Figure 3-2, and consists of the following functional circuits:

1. Analog Signal Conditioning
2. Analog to Digital Conversion
3. Signal Processing and Image Enhancement
4. Data Memories #1 and #2
5. Video Output and Sweep Generator
6. Timing and Control Circuitry

3.1.1.1 Analog Signal Conditioning

The Analog Interface Circuitry serves as the buffering element between the IR detector array and the IRMUX Dual Channel Display Processor. The interface circuitry includes signal level conditioning to insure systems compatibility.

3.1.1.2 Analog to Digital Conversion

The IR detector video signal is converted to digital format for storage in and subsequent retrieval from the display refresh memory which is digital in nature. A real time conversion of the analog signal level produced by each detector is performed.

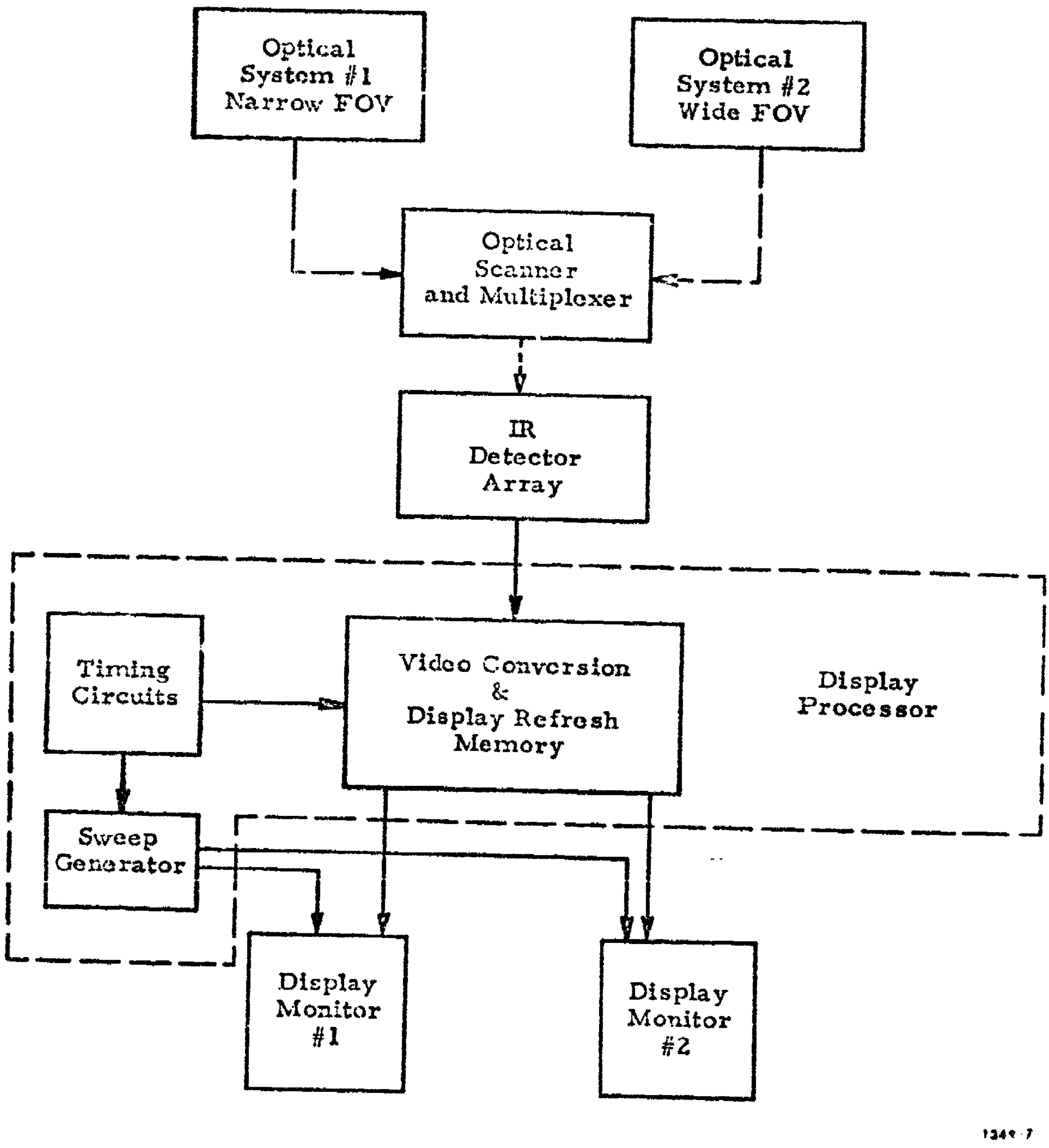
A tradeoff must be made between system cost and physical parameters versus the extent of quantization. Various studies have been made of information requirements for target and pattern recognition. Little information is available, however, upon which to definitize the gray scale requirement for either FLIR or radar displays. A 4 bit system producing 16 distinct shades of gray may be totally adequate for the majority of situations. However, a 6 bit system, providing 64 shades of gray may be minimal in some cases. The capability of the display itself is often a limiting factor. Thus, the requirement for the number of shades of gray must be ascertained for each particular situation.

3.1.1.3 Signal Processing and Image Enhancement

A number of signal processing and image enhancement techniques can be implemented as required by the FLIR system characteristics. The IRMUX Display Processor task consists of synthesizing and implementing a Signal Processor which highlights the salient dimensional or space features of a particular object space. Paragraph 3.4.2 details the most significant characteristics of signal processing and image enhancement possible using the IRMUX dual-channel FLIR mechanization.

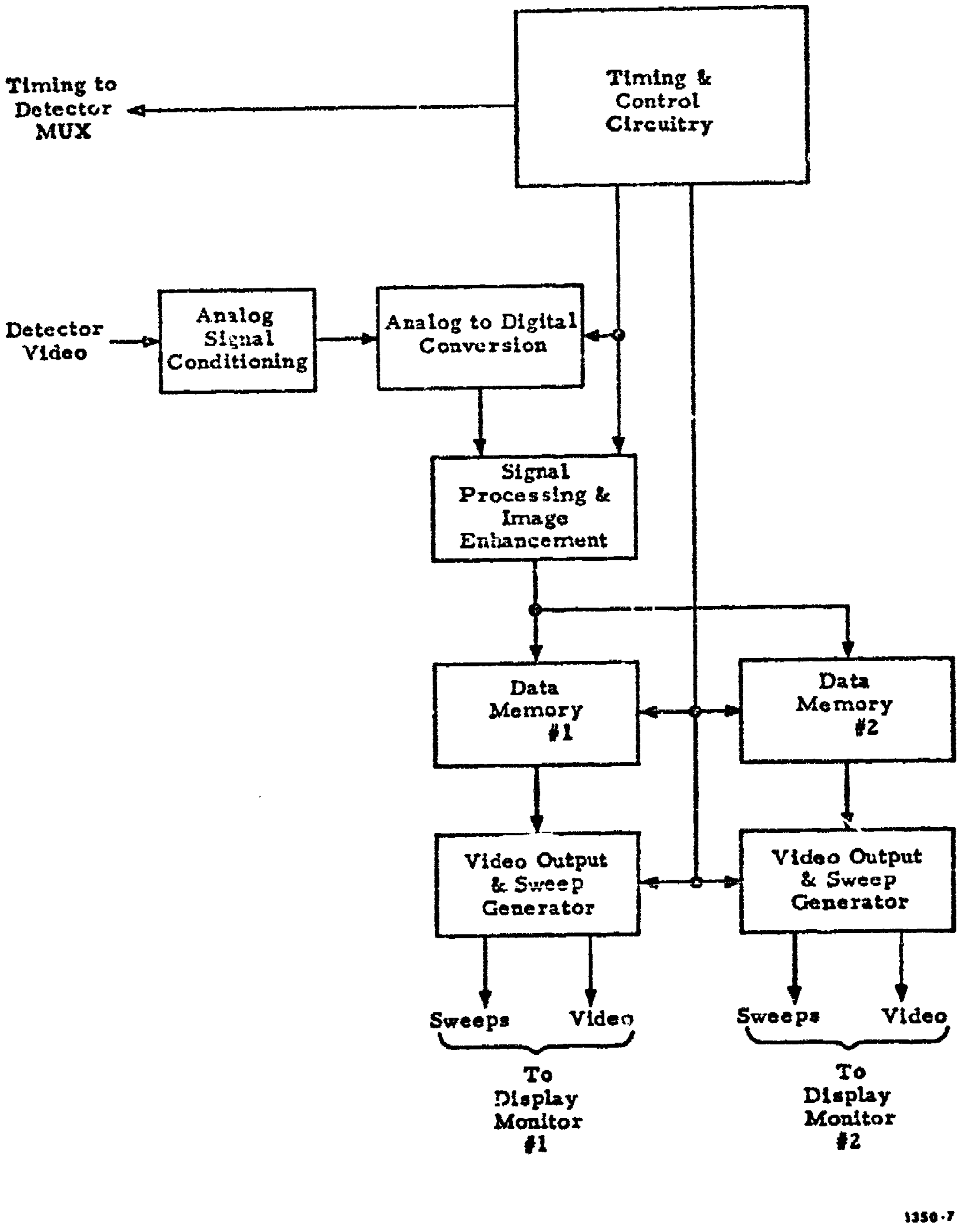
3.1.1.4 Data Memory

The Data Memory serves as the principal processed IR video information storage area. Relatively simple IRMUX systems can be mechanized using direct view storage tubes as the storage medium, whereas more complex display systems will include large digital data memory arrays. Because of the proliferation of new storage techniques and devices, engineering trade-off analyses of performance versus cost versus physical characteristics must be performed during the design phase of each IRMUX Scan Converter. Paragraph 3.3.2 enumerates the major storage techniques as presently applicable to the IRMUX Scan Converter. It is anticipated that the storage characteristics presented therein will serve as a guideline in performing the engineering trade-off analysis.



Dual Channel IR MUX System
Block Diagram

Figure 3-1



Display Processor Block Diagram

Figure 3-2

3.1.1.5 Video Output and Sweep Generator

The Video Output and Sweep Generator provides the synchronizing, blanking, deflection sweep, and analog video signals required to display the IRMUX information on the CRT monitors. Mechanization of these functions is determined by the choice of the display device and data presentation format. Normally two general classes of display types are used for IR systems:

a. TV Raster
b. Patterned Raster

In sophisticated infrared systems, as with airborne early warning, other information may be simultaneously displayed on the CRT monitors; e.g., correlative data from radar, television. An IRMUX Display Processor which time-shares a CRT monitor with other equipment might use a TV Raster format to ease system interfacing constraints. For a simple system such as a hand-held viewer, the most effective display format would be patterned after the object space scan and result in a Patterned Raster Display. Criteria to use in deciding which display format to use are covered in Paragraph 3.2.

Trade-offs must be made of display types versus costs, physical parameters, performance parameters such as resolution, and human factor parameters such as pattern recognition.

3.1.1.6 Timing and Control Circuitry

The IRMUX system timing produces all necessary control and timing relationships. Because of the nature of this study, and the generality of the timing functions, further analysis of system timing can be omitted without degrading the applicability of the modular IRMUX Display Processor Concept. Suffice it to say that all systems will require the timing and control functions with the only differences being the types of IR systems being considered.

3.2 General Analysis

The IRMUX Display Processor description given above indicates the general requirements of a number of FLIR applications. Before derivation of specifics, a digression into IR detector and display parameters, which are modified or influenced by the application of the dual-channel multiplexed optics, is presented.

3.2.1 Multiplexing Scanner

The operation of the optical scanner shown in Figure 2-11 must meet the following conditions:

a) The scanner must dwell on each resolution element for a time greater than the detector time constant.

b) The scanner must be operated at such a rate that no underlap of the FOV occurs.

3.2.1.1 Detector Time Constant

The process by which the detector performs its transducing function under the influence of irradiation can be described as an integration process. For best performance, the time constant of the integration should match the dwell time of the scanner. The basic difference between the dual channel multiplexed optics and conventional IR optics is that the multiplex system must scan through two fields of view in the same time as standard configurations scan only one FOV. If each system matches the integration time of the detector with the dwell time of the scanner, the multiplexed optics would require detectors with twice the bandwidth of the conventional system. The assumption is here made that interlace and refresh rate considerations are the same for each technique.

3.2.1.2 Scan Pattern

Many types of scan patterns and scan methods can be mechanized. For the modular system under consideration, a repetitive raster scan is most suitable for satisfying the requirements of diverse IR image and search systems. In general, rasters are combinations of two orthogonal linear motions, and by proper choice of the detector dwell time and rotational velocity of the mirror, no underlapping of the two FOV's will occur.

3.2.1.3 Display Frame and Field Rates

It is well known that for a CRT display above 100 ft-lamberts in intensity, a frame rate of at least 60Hz is required to obtain a non-flickering presentation of information. In context of the present considerations, a non-flickering display can be obtained by the following techniques:

a) Increase the multiplexed optical scanning rate until the detector array is scanned 60 times per second for 352 elements (no interlace), 30 times per second for 176 elements (2:1 interlace), or 15 times per second for 88 elements (4:1 interlace).

b) Provide a storage matrix of sufficient elements, such that the combination of detector scan and memory scan is at least 60 times per second.

c) Provide a storage matrix of sufficient elements such that the optical input scan and stored display scan are independent.

3.2.1.4 Scan Synchronization

The mechanical aspects of the optical scanning system are such that the IR detectors are arranged in a row of length corresponding to one dimension of the field of view. The rotational movement of the mirror is used to generate the second coordinate by scanning the array about its longitudinal axis. To prevent jitter in the display due to fluctuations in scan-to-scan position errors, synchronization is maintained with respect to the azimuthal position.

3.2.1.5 Platform Stability

Because of the characteristic narrow beamwidth, infrared systems aboard aircraft are sensitive to platform attitude. Display corrections can be made electronically by shifting the raster up and down for pitch, and right and left for yaw, in synchronism with the platform. Targets within the display frame will appear to be stationary, although the frame coordinates move about.

3.2.1.6 Symbology

The dual channel FLIR Sensor displays may have a requirement for overlaid symbology. Since the mission profile has not been delineated at this time, it is premature to enumerate specific symbols and formats. Consideration is being given to including target marker symbols, artificial horizon and steering symbology, and cursors for target designation. It is desirable for these symbols to provide minimum interference and smearing when positioned and moving across stored images. The optimum choice of symbol generator design is a function of the display processor memory device and the display raster format. As such, further consideration of the symbology will be deferred.

3.2.2 Representative IRMUX Display Processers

The techniques given above for obtaining a non-flickering display, outline three possible approaches for the IRMUX mechanization. The different system organizations are not mutually exclusive, but more of a logical progression of increasing performance. In keeping with the modular design philosophy, only an addition of specific functions will be necessary to extend the capabilities of a particular display to the next highest level. Three general system organizations, based on the three approaches, are presented below. The advantages and disadvantages of each technique are tabulated as well as inherent functional limitations.

The threeorganizations are classified as to format and amount of Display Refresh Memory provided. Inherent in the clasifying method is the structuring of a relationship between the input optical scan and the display raster scan and limitations to the types of image enhancement algorithms that can be mechanized. The final IRMUX trade-off analysis must be predicated on a set of system requirements. This Section, therefore, is constrained to enumeration of the functional parameters, advantages and disadvantages, and inherent limitations of each of the three system classes.

3.2.2.1 System I

The organization designated as System I corresponds to the scanning method of

3.2.1.3a above which requires that the detector array duty cycle be increased for the multiplexed system as compared to a single channel unit. Two approaches to satisfying the duty cycle requirement are: to use detectors with increased response characteristics, or to increase the degree of interlacing. While either technique would allow a non-flickering display, both approaches constrain the choice of detectors and scan pattern for a particular application.

The System I configuration uses no display refresh data storage. The input optical scan pattern and field rate must equal the display raster pattern and field rate.

Advantages

1) Lowest possible system cost

2) Most reliable system (least complex)

3) Smallest weight, size and power requirements

Disadvantages

1) Places severe constraints on IR detectors and interlace pattern

2) Could not perform digital image enhancement

3) Difficult to eliminate display flicker

4) Does not supply frame-freeze

System I is not suitable for a modular, expandable system because of the requirements placed on the IR detectors.

3.2.2.2 System II

In this sytem, the detector scan occurs at a normal standard rate. Data storage is provided for only one frame of one display field of view. Video data would alternately be displayed in real time and then repeated via the storage function. The data stored in memory would be alternately narrow and wide fields of view. This is a limitation on the optical scanning systems.

Both display systems would be time-sharing the same data storage function. During frame-freeze, possible on only one display at a time, the un-frozen display would be real time only and would have objectionable flicker. This system is not realizable with storage/scan converter tube mechanizations. In such cases, one display would have full capabilities and the other would have objectionable flicker.

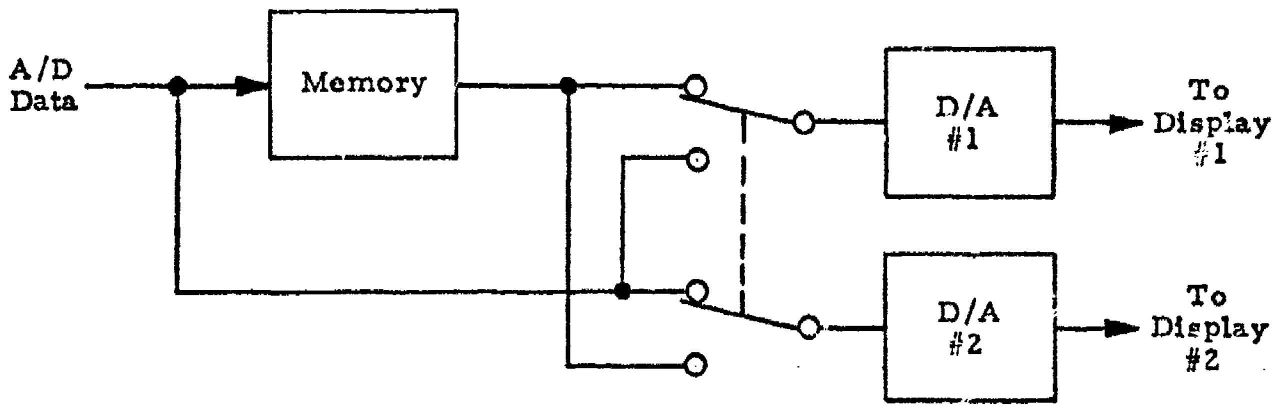
Advantages

1) Low system cost
2) Reliable system approach
3) Low weight, size and power requirements
4) Low development risk

Disadvantages

1) Could perform only limited digital image enhancement
2) Input optical scan must be synchronized to the display scan
3) Allows frame-freeze on one display only
4) Second monitor would have objectionable display flicker when first monitor is frozen.
5) Only realizable with memory devices which allow simultaneous and varying read and write functions, e.g., shift register memory

Figure 3-3 depicts a portion of such a system, including the memory and the switching analogy between A/D, memory, and the two display D/A converters.



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System II Memory Configuration and Switching Analogy

Figure 3-3

3.2.2.3 System III

System III would provide refresh storage of one frame for each display monitor.

Providing a memory for each channel can remove the dependence between display scan and the optical scan technique. It is possible to optimize both the choice of detector, optical scan pattern, and display scan format for each application. System III represents one embodiment of such a system.

Advantages

1) Medium development risk
2) Could perform digital image enhancement
3) Allows simultaneous frame freeze and non-flickering display
4) Input optical scan independent of display scan
5) Maximum performance features

Disadvantages

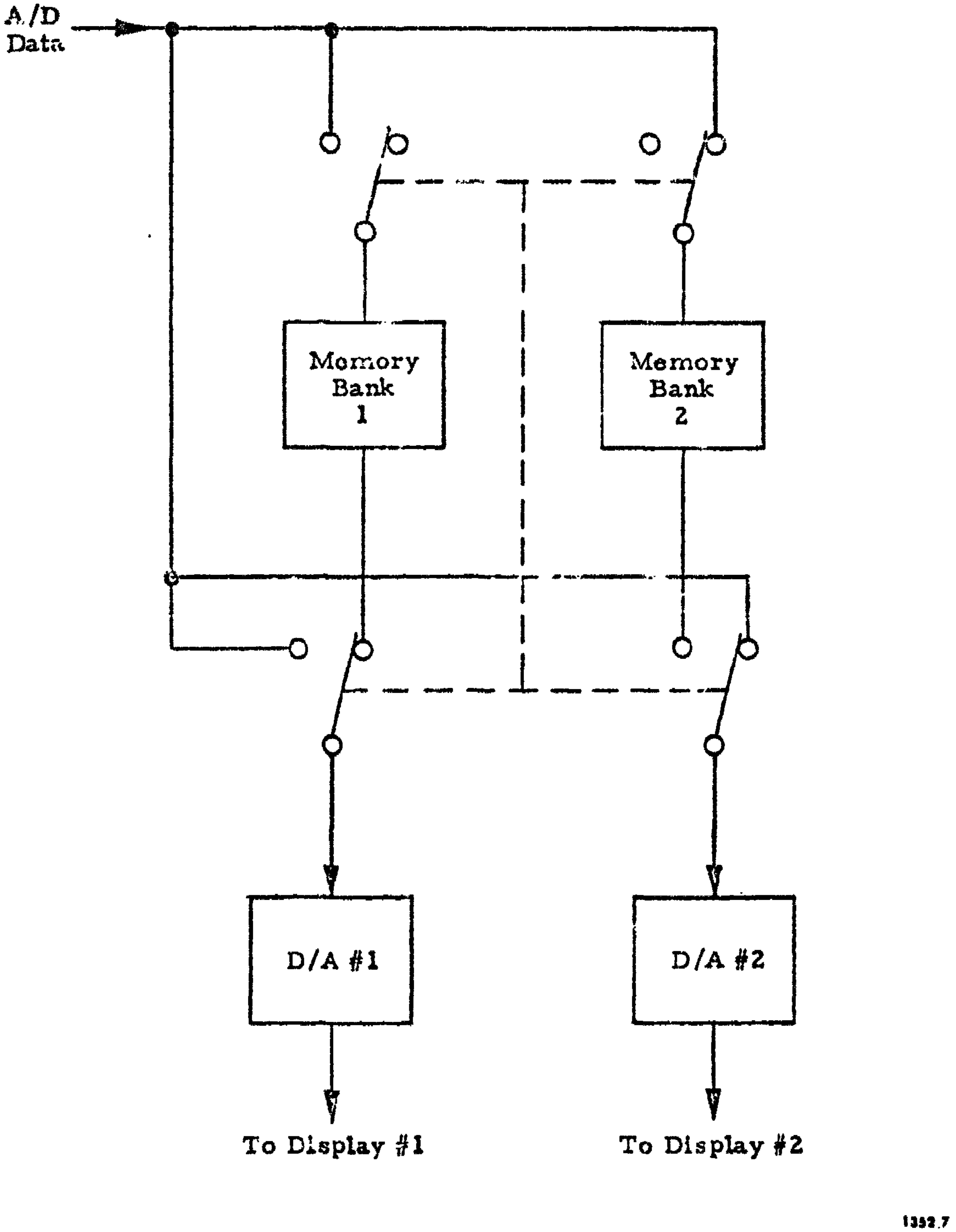
1) Medium system cost
2) **Medium weight, size and power requirements**
3) Medium reliability because of system complexity

Figure 3-4 depicts the memories and switching analogy for this system.

3.3 Data Storage

The IRMUX Display Refresh Memory is intended to provide data storage and format compatibility between the multiplexed optical scan and the display raster scan. The memory device evaluations and trade-off presented in this section are directed toward three principal goals:

a) Establish a modular Refresh Memory architecture that will satisfy a number of IRMUX display applications



System III Memory Configuration
and Switching Analogy

Figure 3-4

b) Optimize the Refresh Memory size, input-output stages, and system timing for each memory device considered

c) Reduce power consumption, size, weight, volume, and cost to a minimum for each system organization

Figure 3-5 is a tabular summary comparing the various memory system types in terms of parameters of interest in the IRMUX system mechanization.

3.3.1 Performance Criteria

It is not possible to determine a memory type that is optimum for all IRMUX applications. Selection must be guided by many considerations, including those of overall IRMUX system objectives. Definite criteria must be defined during system design in order to evaluate the most promising memory technology for a particular application. The following performance criteria are considered the most critical for the dual channel IRMUX Refresh Memory:

a) Organization Format

b) Speed

c) Cost, power, weight and volume

3.3.1.1 Organization Format

The primary organization of the Display Refresh Memory is serial read/serial write. The read and write scans are constrained to be equal for System II, whereas System III may allow an independence between the read and write scanning patterns.

3.3.1.2 Speed

The limiting performance criteria of the IRMUX Display Refresh Memory is speed. The memory must be capable of reading and writing within the minimum allowable cycle times. The required cycle times are defined by the optical scan rate and display scan rate. The display scan rate is determined by the resolution and

A

	Format-Organizational Flexibility	Development Risk	Reliability	Growth Capability	Gray Shades Dynamic Range
1. Direct View Storage Tube	Input scan must match display scan. Separate gun for symbology.	Low	Good because of system simplicity. Long term reliability excellent.	Limited by trade-offs between erasure and resolution. Resolution and shades of gray limited.	Limited to 7-8 gray shades.
2a. Single-ended Scan Converter Storage Tube	Intended only as frame freeze storage. Input scan and output scan can be independent.	Low	Tube subject to wear-out, long term reliability fair.	System parameters fixed by choice of tube. Some growth possible by modification of sweeps and change in resolution. Shades of gray limited.	Can achieve 64 gray shades.
2b. Double-ended Scan Convertor Storage Tube	Modification of sweep circuits allows change in format-organization.	Low	Tube subject to wear-out and alignment problems. Long term reliability fair.	System parameters fixed by choice of tube. Some growth possible by modification of sweeps and change in resolution. Shades of gray limited.	Can achieve 64 gray shades.
3a. MOS Shift Registers	Input scan must match display scan. Organization limited to serial shift formats change by modifying multiplexer.	Low	High	Modular and readily expandable.	Limited only by DAC, ADC, and Display Monitor
3b. MOS Random Access	Modification of timing allows change in organization. Limited by speed, may restrict possible formats.	Low	High	Random and sequential shift scan patterns limited by speed. Modular and readily expandable.	Limited only by DAC, ADC, and Display Monitor
3c. Bipolar Random Access	Modification of timing allows change in organization. High speed enables format changes.	Medium	High	Random and sequential shift scan patterns. Modular and readily expandable.	Limited only by DAC, ADC, and Display Monitor
3d. Charge Coupled Transport	Input scan must match display scan. Organization limited to serial shift formats. Change by modifying multiplexer.	High, Not yet in Production	High	Limited to sequential shift scan patterns. Shows promise of greater speed than standard MOS in digital format. Modular and readily expandable.	Limited only by DAC, ADC, and Display Monitor
4a. Rotating Disc or Drum	Input scan must match display scan. System changes allow some modification of serial/parallel inputs/outputs for organization. Format fixed.	Medium	Subject to head flutter, head crashing, mechanical wear.	Format fixed, difficult to reorganize and expand.	Limited only by ADC, DAC, and Display Monitor
4b. Planar Permalloy	Format-organization fixed by manufacturing processes. Can change to fit application, but not for modular system.	Medium	High	Format fixed by manufacturing. Difficult to reorganize, but can expand.	Limited only by ADC, DAC, and Display Monitor

...ge	Signal Processing	Environmental	Speed Frame Freeze, Storage Time Volatile/Nonvolatile Storage	Input/Output Conversion Circuits-Associated Timing	Size Power Representative Memory
...ay shades.	No digital processing. All analog techniques.	Can be full MIL Spec (MIL-E-5400)	Speed limited only by video amp and deflection drive. Storage time between 1-2 minutes. Volatile writing speed - 60K in/sec.	Input analog buffer. Simple sweep and video drive circuits.	Limited display size, large CRT requires large volume for display indicator with no opportunity for remote electronics.
gray shades.	No digital processing. All analog techniques. Low light level integration.	Can be MIL Spec	Speed limited only by video amp and deflection drive. Storage time between 8-12 minutes. Volatile writing speed - .1 μs/element. OK for 525 TV.	Input analog buffer. Simple sweep and video drive circuits.	Per channel: • 8"W x 8"H x 16"L, • 20-25 pounds • 100-150 watts
gray shades.	No digital processing. All analog techniques. Low light level integration.	Can be MIL Spec	Speed limited only by video amp and deflection drive. Storage time between 8-12 minutes. Volatile writing speed ~ .1 μs/element. OK for 525 TV.	Input analog buffer. Simple sweep and video drive circuits.	Per Channel: • 10"W x 8"H x 16"L • 25-30 pounds • 150-180 watts
DAC, ADC, ...itor	Analog & Digital	Temperature limited to +85°C	Serial multiplexed. Organizational flexibility allows meeting all system speed requirements.	ADC, DAC required. Multiplex timing for serial shift.	Per Channel: 500 in^3 can be organized 4.9" x 7.62" x 12.5" Power required = 90 watts Weight = 15 pounds max Δsize = 50 in^3/100K bits Δpower = 30 watts/100K bits
DAC, ADC, ...ter	Analog & Digital	Temperature limits speed; refresh problem.	Frame freeze - indefinite with power on, volatile, speed adequate for system configuration.	ADC, DAC required. Input/output address multiplex and controller for random access. Buffering for serial shift.	Per Channel: 500 in^3 can be organized 4.9" x 7.62" x 12.5" Power required = 120 watts Weight = 15 pounds max Δsize = 50 in^3/100K bits Δpower = 30 watts/100K bits
DAC, ADC, ...itor	Analog & Digital	Can be MIL Spec at sacrifice of speed. High power requirements may induce performance and reliability difficulties.	Speed more than adequate for system, volatile, frame freeze - indefinite with power on.	ADC, DAC required. Input/output address multiplex and controller for random access. Buffer for serial shift.	Per Channel: • 7.5" x 7.63" x 12.5" • Weight = 18-20 pounds • Power = 200 watts
DAC, ADC, ...itor	Analog & Digital	Temperature limits speed; refresh problem.	Speed adequate for system configuration, volatile, frame freeze - indefinite with power on.	ADC, DAC required for digital shift register operation. Multiplex timing for serial shift.	N/A No production devices yet available
ADC, DAC, ...itor	Analog & Digital	Can be MIL Spec. Temperature OK; shock, vibration poor.	Serial multiplexed. Adequate speed, nonvolatile, frame freeze - indefinite.	ADC, DAC required. Multiplex timing for serial shift. Electro-mechanical drives. Input/output buffering for speed.	Per Channel: 10" x 11" x 15" = 1650 in^3 Power = 250 watts Weight = 25 pounds
ADC, DAC, ...itor	Analog & Digital	Can be MIL Spec. Limited by input/output circuits.	Serial multiplexed. Speed marginal, nonvolatile, frame freeze - indefinite.	ADC, DAC required. Requires considerable input/output buffering to obtain desired speed.	1520 in^3 can be organized 19"W x 10"D x 8"H Power required 163.7 watts operating 63.7 watts quiescent Δsize = 100 in^3/100K bits Δpower = 11 watts/100K bits

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Figure 3 - 5 Memory System Trade Off Summary

format of the monitor.

3.3.1.3 Cost, Power, Weight, and Volume

These four parameters are grouped together because they vary in direct proportion to the number of grey shades and to the system speed. A delta factor is given to allow extrapolation of cost, power, weight, and volume as affected by a decrease or increase of grey shades and monitor resolution.

3.3.2 Candidate Data Storage Mechanizations

The data storage mechanizations under consideration are as follows:

a) Direct View Storage Tube

b) Scan Converter Tubes
   - Single Ended
   - Double Ended

c) Semiconductor Memory
   - MOS Shift Register
   - MOS Random Access
   - Bipolar Random Access
   - Charge Coupled Transport

d) **Magnetic Memory**
   - Magnetic Disc
   - Magnetic Drum
   - Planar Permalloy

3.3.2.1 Direct View Storage Tube

The direct view storage tube is an electrical input-visual output storage device. The DVST would find application in the System I configuration where the operator has little time pressure and no competing tasks, and in systems where cost is of overriding importance. A number of construction techniques are grouped into this heading including both long persistence phosphor CRT's and multi-mode tonotrons.

3.3.2.2 Scan Converter Tube

The scan converter storage tube functions as an electrical input-electrical output storage mechanism. The tube is a CRT which has one or more electron guns, each with a beam collimating system and dielectric disc charge storage area. Stored information may be read out with the same electron gun and deflection system (single-ended scan converter with time-shared read and write), or with a separate electron gun for simultaneous read and write (double-ended scan converter).

3.3.2.2.1 Single-Ended Scan Converter Tube

The single ended scan converter tube prohibits the simultaneous read and write functions. This device could find application in systems in which other storage is not sufficient to allow frame-freeze.

3.3.2.2.2 Double-Ended Scan Converter Tube

The double-ended scan converter storage tube provides a number of advantages when compared to other memory devices considered herein. The most significant performance characteristic of a tube scan converter is its ability to integrate low light levels while scanning to provide an enhancement in video output. Another consideration in the middle range systems is the elimination of the analog-to-digital and digital-to-analog converters. Without the quantizer, the system would be constrained to only analog signal processing and could not include any of the available digital enhancement algorithms.

3.3.2.3 Semiconductor Devices

Because of the proliferation of new semiconductor memory techniques, the device types enumerated in this study have been restricted to components in, or nearing, production.

3.3.2.3.1 MOS Shift Register, MOS Random Access

The MOS devices, both P channel and N channel, make use of the temporary storage of data on the parasitic capacitance within the IG MOS FET circuit. To prevent loss of data, this charge must be restored by recirculating of data every few milliseconds.

3.3.2.3.2 Bipolar Random Access

Bipolar devices offer the advantages of high speed, static storage (no refresh needed) and compatibility with T^2L logic. In comparison with other memory devices, the high cost per bit and high power consumption restrict the use of Bipolar RAM's to areas in the image enhancement signal processing where its other qualities are primary requirements (e.g., speed, etc.).

3.3.2.3.3 Charge Coupled Transport

Two basic types of storage devices have been developed using the charge coupled transport phenomenon: charge coupled device (CCD) and bucket brigade device (BBD). These devices are basically dynamic shift registers that can be connected to form the serial in-serial out memory. Both the CCD and BBD function by manipulating charge along a series of electrodes without requiring contact to the silicon. The CCD stores the charge in potential wells, and moves these wells from electrode to electrode, whereas the BBD controls the charge by means of transistors and capacitors.

3.3.2.4 Magnetic Memory

The memory families which operate on a magnetic flux principal can be divided into two categories: mechanical rotating storage and non-mechanical storage.

3.3.2.4.1 Magnetic Disc

The magnetic disc consists of a circular metal plate coated on both sides with a magnetic iron oxide. Data is read or written on the disc using transducing heads fixed over a particular track (head per track) or moved from track-to-track by servo system.

3.3.2.4.2 Magnetic Drum

The magnetic drum is a cylinder, the periphery of which is coated with iron oxide. The magnetic drums under consideration are normally operated in a head per track mode.

3.3.2.4.3 Planar Permalloy Memory

The planar permalloy storage system fabricates toroidal cores and sense wires directly on the surface of an epoxy glass substrate using photographic techniques. The memory structure then becomes an integral part of the substrate and results in a rugged assembly.

3.3.3 Evaluation of Candidate Storage Devices

3.3.3.1 Approach (1): Direct View Storage Tube

Use a direct view storage tube for each display required. Input scan pattern and rate will match display scan pattern and rate.

Advantages

a) Lowest cost, weight, volume, and power of all mechanizations considered

b) Development risk is minimal

c) Target enhancement by the eye in variable persistence tubes

Disadvantages

a) Image fade and smearing degrade pattern or target recognition

b) Additional components required (second electron gun and drive circuits) for simultaneous display of stored image and non-stored symbology

c) Gray scale dynamic range limited

d) Low brightness and contrast ratio in a high ambient environment

e) Low growth capability

f) No digital signal processing possible

g) Display units are large due to tube size. No possibility for remote functions

3.3.3.2 Approach (2): Scan Converter Tubes

Approach (2a): Single-Ended Tube

The only application considered for the single-ended scan converter tube is the frame-freeze mode in Systems I, II, and III. In this mode, the tube would be competing with equivalent digital or magnetic storage devices.

Advantages

a) Lower cost, weight, volume and power than competing systems

b) Low development risk

c) Target enhancement of signals by integration and noise cancellation performed by the grey scale retention

Disadvantages

a) Image fade and smearing de[illegible]e pattern or target recognition

b) Complex timing required to [illegible] symbols by selective raster brightening

c) Growth capabilities limited

d) No digital signal processing possible

e) Electrostatic and magnetic shielding required

f) Poor maintenance characteristics

g) Lower reliability than competing systems

Approach (2b): Double-Ended Tube

This configuration would use a double-ended scan converter tube as the principal display storage device. There would be one tube for Systems II while System III would require two converter tubes. The double-ended scan converter tube would be competing with similar digital and magnetic storage matrices.

Advantages

a) Lower cost, weight, volume and power than a digital or magnetic storage system

b) "Low plus" development risk

c) Target enhancement of signals by integration and noise cancellation performed by the grey scale retention

d) Medium growth capability in system organization

e) Simple read and write scan circuitry

Disadvantages

a) Image fade and smearing degrade pattern or target recognition

b) Changing symbology will smear if not erased before writing.

c) Precise read-write registration is difficult using two or more electron guns.

d) Electrostatic and magnetic shielding is required to prevent external radiation from producing spurious signals in the output.

e) Alignment and packaging difficult for field installations

Low tube life (maintenance required) and reliability

3.3.3.3 Approach (3): Semiconductor Memories

Approach (3a): MOS Shift Register

The MOS Shift Register can be used for the Display Refresh Memory and/or as a frame-freeze storage device. It is anticipated that input multiplexing/output demultiplexing will be required for the P channel devices to achieve the required system scanning rates. New technologies, such as silicon-on-sapphire and complementary MOS, have been announced and are being evaluated at this time. The new components would allow the desired system scan rates to be obtained without device muliplexing. Since the memory system organization would be the same for all MOS shift registers, both standard and new technologies are grouped together for the evaluation.

Advantages

a) Shift register organization complements repetitive raster scans

b) Timing and control circuits less complex than competitive components

c) Lower power consumption that (3b, c) and (4a,b)

d) Allows implementation of digital signal enhancement algorithms

e) No image smear or fading; frame-freeze continuous with power on

f) Stored or non-stored symbology will not smear on the display monitor.

g) Ideal growth characteristic: New high density devices directly applicable to achieve size/cost reductions

Disadvantages

a) Requires analog-to-digital and digital-to-analog converters

b) Higher power consumption than Approaches (1), (2a, b), (3 d), and (4 b)

c) Limits the input optical scan to a sequential raster; shift registers difficult to organize for independence between input scan and display scan

d) Low level signal integration must be performed externally to the Refresh Memory

Approach (3b): MOS Random Access

The MOS Random Access storage devices have characteristics similar to the MOS Shift Registers. At the present time, the cost of both types of components for comparable speed and storage density is roughly equal.

Advantages

a) Allows independence between input scan and display scan

b) Random Access Memories allow the most flexible system organization

Disadvantages

a) Greater power than MOS shift registers

b) Complex timing and system control functions

c) Limited environmental range

e) Requires analog-to-digital and digital-to-analog conversion

f) Low level signal integration must be performed external to the Refresh Memory

Approach (3c): Bipolar RAM

The Bipolar RAM memory devices will allow the same Refresh Memory system organization as the MOS RAM. In general, the RAM components (both MOS and Bipolar) are more suited to modular systems because of the facility by which the memory architecture may be modified.

Advantages

a) Highest speed of all storage components considered

b) Allows independence between input scan and display scan

c) Allows most flexible system organization

Disadvantages

a) Greatest cost and power consumption of all components considered

b) Complex timing and system control functions

c) Requires A/D and D/A conversions

Approach (3d): Charge Coupled Transport

The Charge Coupled Transport technique is relatively new. Laboratory evaluation tests are only now being performed on the bucket brigade devices (BBD and charge coupled devices (CCD). Both are basically MOS shift registers with the potential of very high density and very low cost. They would be ideal for repetitive sequential memory organizations such as are possible in certain IRMUX systems

Advantages

a) Does not require an analog-to-digital or digital-to-analog converter (BBD only)

b) Lower power and cost, and ultimately volume, than all other competitive memory devices

Disadvantages

a) The state of the art is such that these are still laboratory devices. Devices are not yet readily available for large scale applications.

b) The BBD stores an analog signal and suffers from signal leakage and low storage time constants

c) Number of registers limited by the cumulative signal step response error

The BBD can be connected as a binary shift register and would then fall into the MOS shift register evaluation given above. The BBD would have a lower power dissipation than comparable MOS registers.

3.3.3.4 Approach (4): Magnetic Memories

Approach (4a): Rotating Disc or Drum

The rotating magnetic memories are normally a serial in-serial out storage matrix with random access on a block basis. The data transfer rate is too slow or buffer storage too large to offer serious competition to semiconductor memories. For the sequential scan optical inputs, a dual disc/drum memory with a parallel word output would be a reasonable approach.

Advantages

a) Relatively low cost

b) Power, weight, and volume less than other systems, except (3d)

c) Non-volatile storage

Disadvantages

a) Disc memories cannot withstand severe shock or vibration.

b) Both disc and drum memories must be sealed against contamination

c) Cost of extreme environment unit greater than (2b) and (3a, b)

Approach (4b): Planar Permalloy Memory

The planar permalloy system would be organized word serial, bit parallel. This system offers MIL-E-5400M, Class 2 performance.

Advantages

a) Lower power than semiconductor or scan tube memories

b) Rugged assembly suitable for airborne or space applications

c) Medium cost

d) Non-volatile storage

Disadvantages

a) Format fixed by manufacturing techniques; most suited to serial shift register organizations

b) Access rate slow; requires input/output buffering to achieve system speed required

3.4 Image Enhancement

For the analysis performed herein, the term image enhancement is defined to be these electrical and optical processes whereby the Display System manipulates the scanned object space brightness function. The enhancement methods considered below will be limited to those techniques which improve the interpretation of information by a human operator.

3.4.1 Display Requirements

In the IRMUX System, the CRT indicators are the primary man-machine display interface. It is this interface which serves as the ultimate criteria of real time multiplexed FLIR system performance. In general, the image enhancement requirements of the IRMUX consists of expanding the display size and resolution into a sufficient viewing area for target detection and recognition. Each CRT display element represents the least geometrical detail which can be discerned in the target and corresponds to the highest angular resolution of the FLIR optical system.

Two fundamental display problems exist in transforming the information in the object space brightness function into the form required for target detection and pattern recognition: the dynamic range-contrast ratio condition and the coarse scan quantization.

3.4.1.1 Dynamic Range-Contrast Ratio

Ideally, the dynamic range (grey shades) of the CRT indicators should match the dynamic range of the infrared detector matrix. Each grey shade increment would then reflect the minimum thermal resolution of the array. Three factors necessitate a deviation from the ideal case: the effect of video quantizing rate on image interpretation, the contrast ratio required to display a large number of grey shades, and the increase in refresh storage complexity. The greater the number of grey shades presented to the operator, the easier the task of map interpretation. The quality of a monochromatic image versus grey shades curve is linear to approximately 128 levels, at which a significant flattening of the curve occurs. The deviation from linearity occurs in a system with a limited maximum quantizing rate because the amount of amplitude change available does not correspond to a better reproduction of higher spatial frequencies. To maximize the image quality versus grey shades response, the video quantizing rate would have to be increased (increasing the number of detectors).

From a display design standpoint, sunlight shining directly on the CRT phosphor represents the most severe lighting condition. To provide only seven shades of grey under a 10,000 ft-candles ambient condition would require a 3000 ft-lambert display brightness and a very efficient contrast enhancement filter. A reduction in the contrast ratio, due to such factors as ambient illumination, will eliminate the part of the grey scale curve where most of the brightness steps occur.

As pointed out in the Memory Device Analysis, an increase in the number of grey shades can be obtained at the expense of increasing the size and complexity of Display Refresh Memory.

Limitations of the Display System demand a compromise solution to the functional dynamic range. The grey shades should be specified by the visual interpretation requirements placed on the operator for a particular range of applications. The limits in grey shade magnitude will be constrained to be between 16 shades and 128 shades. Analog Signal Processing techniques can be added to compensate, in part, for the decrease in display system response.

3.4.1.2 Quantization

The scanning of the object space by the IR detector array quantizes the infrared video into discrete display elements. Because of this quantization, the video data presented to the display exhibits a fine structure which is anisotropic.

3.4.2 Enhancement Techniques

The performance of an IR imaging system is limited by the ability of the eye to perceive intensity differences between one part of the image and an adjacent one. This ability is reduced when the average intensity of the image increases due to a uniform addition of intensity to all parts of the image. It is therefore necessary to suppress any information which merely increases the average recorded intensity without adding information about the individual elements. This can be achieved by optical and, when applicable, by electronic means. Three classes of image enhancement techniques will be considered below:

1) Spatial (Optical) Filtering
2) Analog Signal Processing
3) Digital Signal Processing

3.4.2.1 Spatial Filtering

The fundamental object of space filtering is to highlight the salient dimensional or space features of a particular object at the expense of dimensional detail received from undesired radiation. Optical space filtering is most frequently performed by the field stop and/or reticle located at the focal plane of the imaging optical system. The primary consideration given to the mechanization of optical spatial filtering has been to insure that the optical multiplexing schemes under consideration do not inhibit the inclusion of this form of enhancement.

Preliminary inspection has indicated that spatial filtering could be included in the multiplexed optical system. The single constraint is that the same filtering technique must be performed on both the wide FOV and the narrow FOV. Further analysis will be performed upon definition of the space filtering requirements.

3.4.2.2 Analog Signal Processing

The main consideration in the analog signal processing is that of maintaining detector-to-detector consistency within the array. Calibration controls should be included in the system front end so that detector responce as seen at the output of the analog signal processing can be aligned. The detector preamplifier frequency responses must be closely matched and an Automatic Gain Control loop included to insure that the average noise level out of all detectors is the same.

3.4.2.2.1 Reverse Video

In an imaging system in which the processed IR video has substantial average intensity, an increase in recognition capability can be obtained by displaying the negative image (display intensity decreases with an increase of incident radiation).

3.4.2.2.2 Gamma Correction

The Gamma Correction circuit is used to compensate for the limited dynamic range of the grid-modulated CRT monitor. The gamma correction compresses the IR video signal, which has a greater dynamic range than that of the CRT, so that the stronger video signals will not "bloom" the CRT phosphor. The response curve of the gamma correction is made continuously variable so that a contrast adjust of weak signals with respect to strong signals can be obtained. This adjustment allows the nulling out of a narrow range of background intensities to enhance the image contrast ratio.

3.4.2.3 Digital Signal Processing

A direct definition of the Digital Signal Processing is possible using the following considerations. The IR input signal can be considered as a real valued function of two variables, say $g(W_x, W_y)$ (brightness function, whose plane is defined by W_x and W_y). The display raster scan is then defined as an array of real variables, $\{A_k\}$, where A_k is a scan element. The indices $\{K\}$ are an ordered set of integers; $\{A_k\}$ belongs to a finite-dimensional vector space. The Digital Signal Processing follows as an operation of constructing a sequence of real variables $\{A_k\}$ from a given signal $g(W_k, W_y)$ such that a desired degree of video information is preserved. The Signal Processing techniques considered below are concerned with decreasing the objectional contours caused by quantization of the image brightness function.

The enhancement methods considered herein are:

1) Etching the CRT face to perform a 2-dimensional smearing of the display elements

2) Adding a pseudorandom dither to break up the objectional contours caused by coarse quantization

3) Edge Amplitude distortion which modifies the intensity of edge transitions but preserves regions of constant intensity

All three enhancement techniques employ synthetic random distortions to the spatial response of the display to reduce the objectional contours caused by course quantization. The major problem inherent in all methods is the loss of CRT spot size resolution and accuracy. The resolution detail is traded for an increase in pattern recognition and interpretation capability.

3.4.2.3.1 Two Dimensional Smearing

Although the CRT face etching is not a digital technique, it is inserted in this section as an alternate approach to the digital algorithms. The 2-dimensional smearing of the CRT indicator face acts as a low pass filter on the spatial response of the CRT visual output. The lower frequencies as seen by the operator effect a smoothing function of edge transitions.

3.4.2.3.2 Pseudorandom Noise

This approach takes advantage of the decreasing sensitivity of the eye to noise of increasing frequency. A dither signal is algebraically summed with the quantized video data to effect the modulation of the signal by pseudorandom noise. The waveform perceived by the operator now lies closer to the target physical geometry because the visual filtering attenuates the error which is at higher spatial frequencies.

3.4.2.3.3 Edge Amplitude Distortion

This enhancement technique uses a classifying algorithm to examine the display detail element-by-element. In regions which exhibit a constant magnitude, no correction is performed. At edges, or transitions of magnitude, an amplitude distortion is introduced to break up the edge contours. The apparent edge position must be reproduced accurately along with preserving regions of constant intensity.

3.5 Trade-Off Summary

A quantitative means of comparing the IRMUX system organization and the memory types are included herewith. To establish the relative merit of each candidate solution, a list of considerations was set down together with an order of importance for each. Each candidate solution is then assigned a weighting factor for each consideration. The resulting relative merits for all considerations are summed to determine an overall relative merit.

Figures 3-6, 3-7, 3-8 present the analyses for (a) IRMUX System Organization, (b) Memory Type selection, and (c) Semiconductor Type selection.

The considerations and orders of importance, on a scale of eight, are:

Consideration	Order of Importance
Weight	6
Volume	6
Reliability	6
Growth Potential	4
Power	5
Technical Risk	4
Cost	4
Performance	6

DESIGN TRADE OFF EVALUATION SHEET

INSTRUCTIONS

1. Enter Choices (vendors, options, sources, etc.)
2. Determine applicable considerations (choose part or all listed, add if needed)
3. Assign order of importance to applicable considerations - 1 through 8 if there are 8 applicable considerations (1 is low). Several considerations may have the same order of importance.
4. Assign weighting factor to each choice for every applicable consideration
5. Multiply "order of importance" times weight (wt) to obtain "RM"
6. Add each column of Relative Merit (RM)
7. Select choice having highest Relative Merit

Weights			
	8 Extremely desirable	5 Satisfactory	2 Bad
	7 Desirable	4 useable	1 Very bad
	6 Better than most	3 Questionable	0 Unacceptable

Considerations	Order of Importance	System I		System II		System III			
		Choice		Choice		Choice		Choice	
		wt	RM	wt	RM	wt	RM	wt	RM
Weight	6	7	42	6	36	5	30		
Volume	6	6	36	6	36	5	30		
Reliability	6	4	24	5	30	5	30		
Growth Potential	4	4	16	5	20	6	24		
Power	5	7	35	6	30	5	25		
Technical Risk	4	2	8	4	16	5	20		
Cost	4	7	28	6	24	5	20		
Performance	6	2	12	3	18	7	42		
Total Relative Merit			201		210		221		

Figure 3-6

IRMUX System Organization

DESIGN TRADE OFF EVALUATION SHEET

INSTRUCTIONS

1. Enter Choices (vendors, options, sources, etc.)
2. Determine applicable considerations (choose part or all listed, add if needed)
3. Assign order of importance to applicable considerations - 1 through 8 if there are 8 applicable considerations (1 is low). Several considerations may have the same order of importance.
4. Assign weighting factor to each choice for every applicable consideration
5. Multiply "order of importance" times weight (wt) to obtain "RM"
6. Add each column of Relative Merit (RM)
7. Select choice having highest Relative Merit

Weights	8 Extremely desirable	5 Satisfactory	2 Bad
	7 Desirable	4 useable	1 Very bad
	6 Better than most	3 Questionable	0 Unacceptable

Considerations	Order of Importance	Direct View Storage Tube		Scan Converter Tube		Semiconductor Memory		Magnetic Memory	
		Choice		Choice		Choice		Choice	
		wt	RM	wt	RM	wt	RM	wt	RM
Weight	6	7	42	6	36	6	36	5	30
Volume	6	7	42	4	24	6	36	5	30
Reliability	6	6	36	5	30	6	36	6	36
Growth Potential	4	2	8	6	24	7	28	6	24
Power	5	5	25	6	30	7	35	6	30
Technical Risk	4	7	28	6	24	6	24	5	20
Cost	4	6	24	4	16	6	24	4	16
Performance	6	4	24	5	30	7	42	6	36
Total Relative Merit			229		214		261		222

Figure 3-7

Memory Type Selection

DESIGN TRADE OFF EVALUATION SHEET

INSTRUCTIONS

1. Enter Choices (vendors, options, sources, etc.)
2. Determine applicable considerations (choose part or all listed, add if needed)
3. Assign order of importance to applicable considerations - 1 through 8 if there are 8 applicable considerations (1 is low). Several considerations may have the same order of importance.
4. Assign weighting factor to each choice for every applicable consideration
5. Multiply "order of importance" times weight (wt) to obtain "RM"
6. Add each column of Relative Merit (RM)
7. Select choice having highest Relative Merit

Weights			
	8 Extremely desirable	5 Satisfactory	2 Bad
	7 Desirable	4 useable	1 Very bad
	6 Better than most	3 Questionable	0 Unacceptable

Considerations	Order of Importance	MOS Shift Register Choice		MOS Random Access Memory Choice		Bipolar RAM Choice		Charge Coupled Devices Choice	
		wt	RM	wt	RM	wt	RM	wt	RM
Weight	6	6	36	6	36	6	36	7	42
Volume	6	6	36	6	36	6	36	7	42
Reliability	6	5	30	5	30	5	30	7	42
Growth Potential	4	5	20	6	24	6	24	5	20
Power	5	6	30	5	25	3	15	6	30
Technical Risk	4	7	28	6	24	5	20	2	8
Cost	4	7	28	5	20	3	12	2	8
Performance	6	5	30	6	36	6	36	5	30
Speed	4	5	20	5	20	6	24	5	20
Availability	6	7	42	5	30	4	24	1	6
Flexibility	6	4	24	7	42	5	30	4	24
Total Relative Merit			324		323		287		272

Figure 3-8
Semiconductor Type Selection

These rankings presume a dual display system in a military environment, e.g., a helicopter with a need for simultaneous viewing, and a relatively near-in production time table. Situations with less stringent ground rules could lead to different conclusions.

As seen in these figures, a System III organization, that is, a full two display channel refresh memory mechanized via a MOS shift register or random access semiconductor memory is indicated numerically by this analysis.

3.6 TYPICAL DISPLAY PROCESSOR CONFIGURATIONS

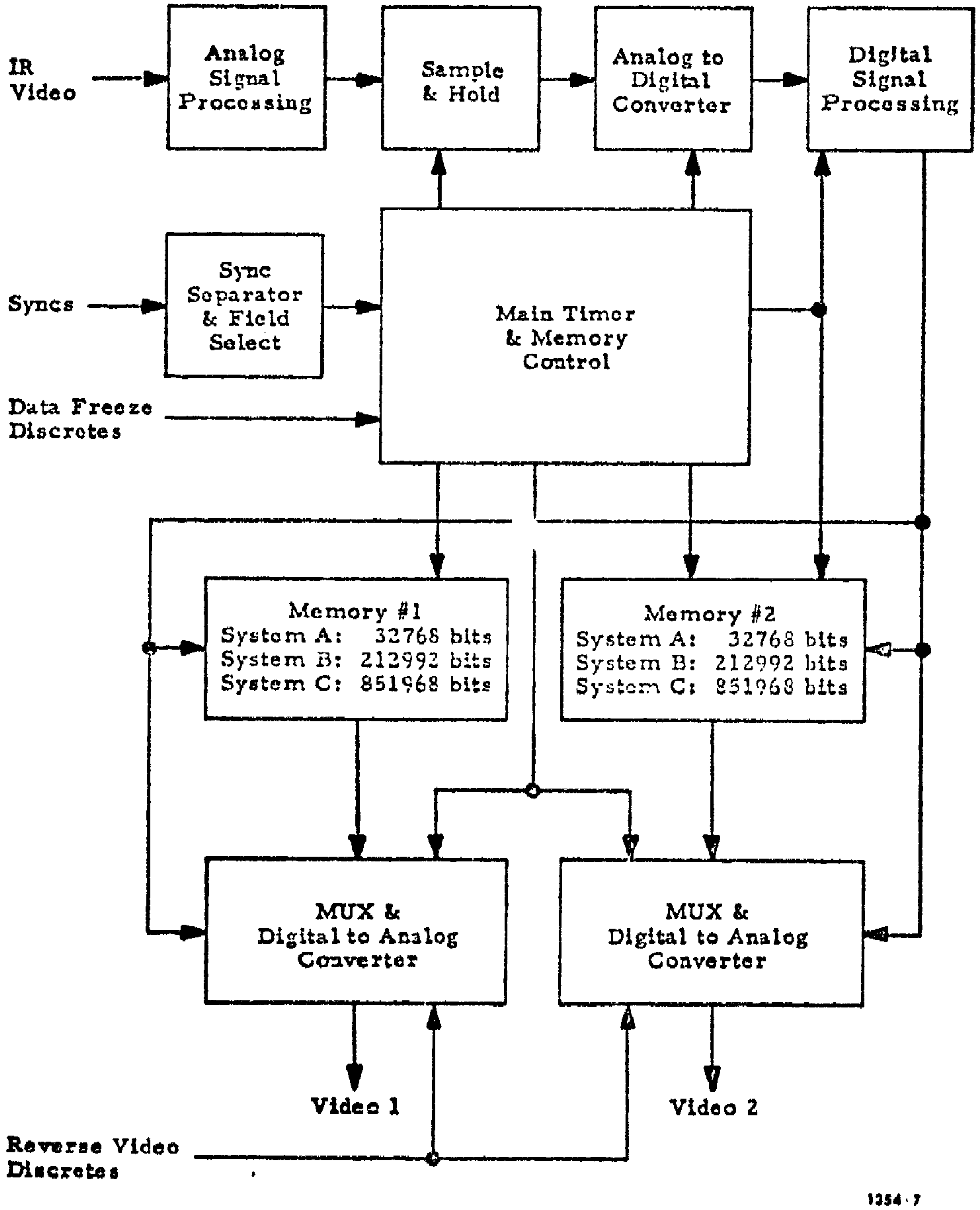
Three typical IRMUX systems have been analyzed both optically and electrically during this study program. The mechanization of the Display Processor for each is presented in subsequent paragraphs. Figure 3-9 is a general System Block Diagram applicable to all three examples. The memory size for a 16 shades of grey system of each type is included in the memory block.

3.6.1 System A - Hand-Held Thermal Viewer

The Hand-Held Thermal Viewer AN/PAS-7 was studied as it is the most readily available system to use in demonstrating the IRMUX concept quickly and inexpensively. Two mechanizations for this system are presented. The first, presented below, is a minimal cost approach using the existing HHTV CRT and circuits. It is limited in terms of image processing and display refresh rates. The second and recommended approach is presented in Section 4.

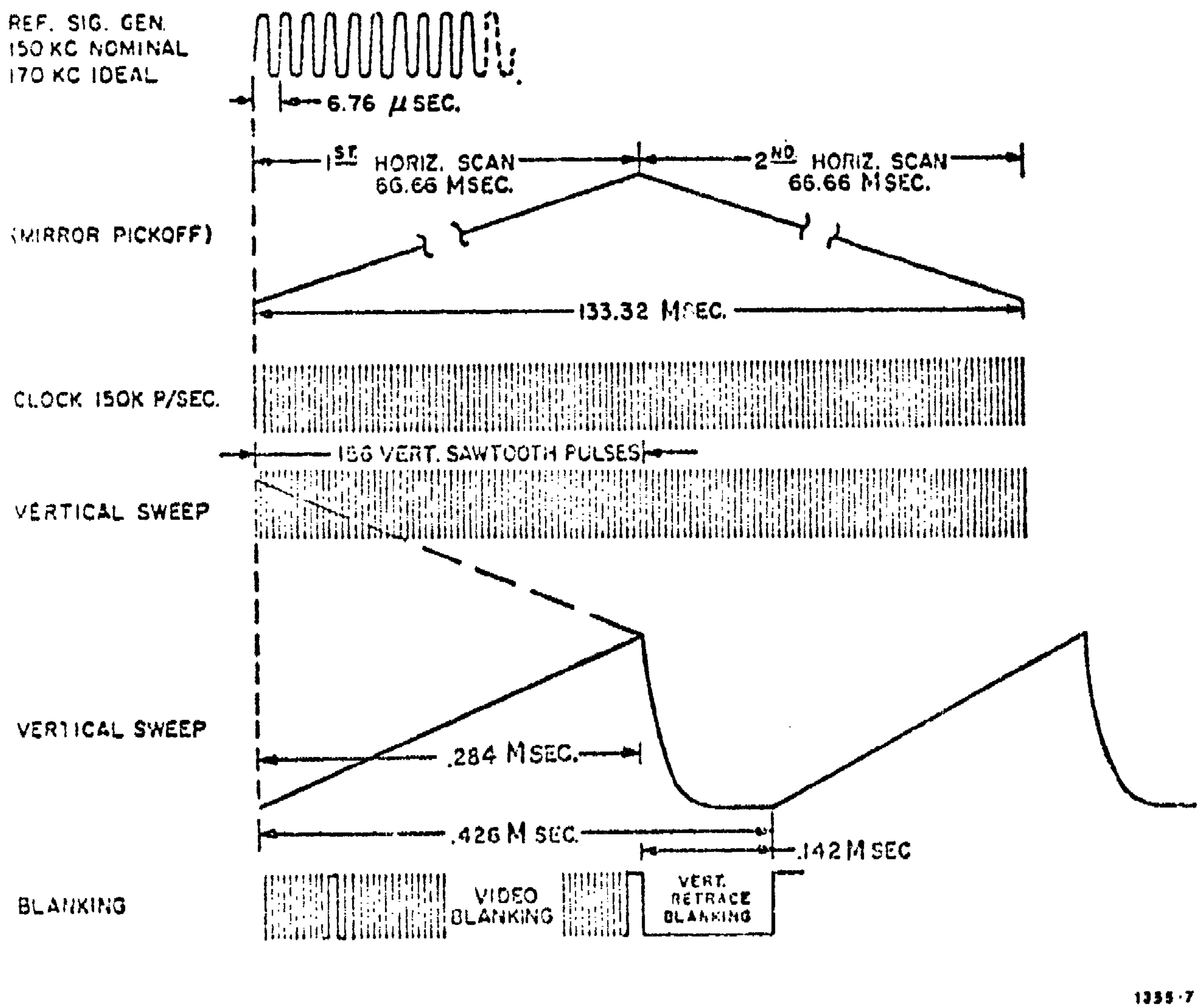
Figure 3-10 is the timing chart for the HHTV system. Note that this is a bi-directional horizontal scan with a 1:1 interlace. To mechanize the IRMUX concept with this system with minimal hardware impact, it is desirable that no changes be made to the timing or the sweep circuits. This, coupled with the 1:1 interlace and bidirectional scan dictates the use of a random access memory rather than a shift register memory as data is stored during one frame and must be read out in opposite order during the subsequent frame to maintain left-right orientation. Here, then, is an aspect of a specific system which modifies the tradeoff study.

A summary of system parameters of concern in this mechanization follows:



System Block Diagram

Figure 3-9



HHTV Timing

Figure 3-10

3.6.1

SYSTEM A

Hand-Held Thermal Viewer

. Picture Bits:	7500 nominal
. Frame Rate:	15 frames per second
. Interlace:	1:1
. Number of Detectors:	48
. Horizontal Frame Time:	66.66 milliseconds
. Number of Detector Samples, Horizontal:	156
. Horizontal Scan Pattern	Alternating left to right, right to left, Bidirectional
. Scan Duty Cycle:	0.95
. Number of Vertical Lines	156
Total:	0.426 milliseconds
Active:	0.284 milliseconds
Retrace:	0.142 milliseconds

. Sample Time per Detecor: $\frac{0.284 \times 10^{-3}}{48} = 5.91 \times 10^{-6}$ seconds

. Sampling Rate: 170KHz

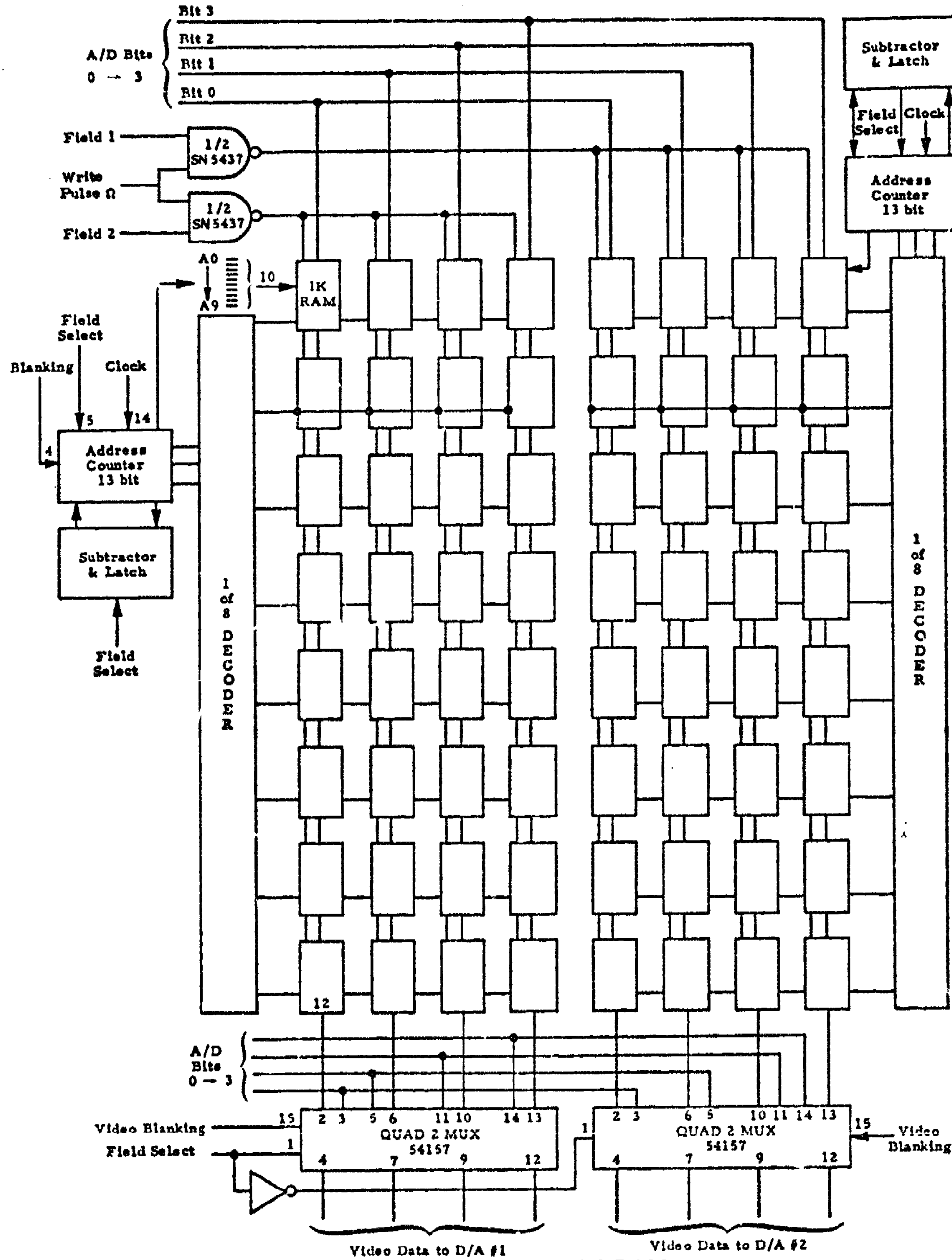
. Memory Size per FOV: 48 x 156 = 7488 per SOG bit

. Total Memory = 29952 per Memory for 16 shades of grey (32768 in nearest binary configuration)

• Need Random Access or Reversible Shift Register capability to accommodate alternating scan without modification of existing viewer circuits.

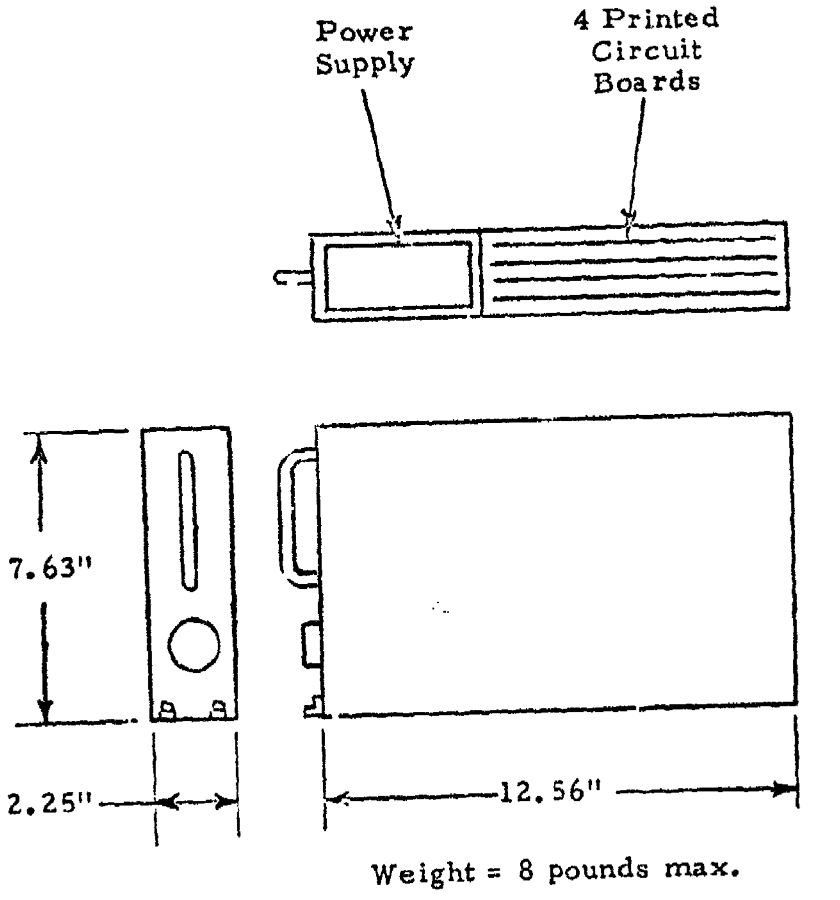
Figure 3-11 is a block diagram of the two memory functions as well as addressing and multiplexing logic to the component level. The use of 1024 bit MOS random access memories is shown.

The entire Display Processor for the HHTV System A, including dual memory can easily be packaged into a 1/4 ATR short package. The dimension of this unit are shown in Figure 3-12. Unit weight would be less than eight pounds. Unit power would be less than 25 watts.



HHTV System A, Using 1K RAM

Figure 3-11



Display Processor, Hand Held Thermal Viewer, System A

Figure 3-12

3.6.2 SYSTEM B - Universal Viewer

The characteristics of a hypothetical System B, somewhat more complex than the Hand-held Thermal Viewer, are summarized below. Note that the scan sequence is such that by storing a frame of data, the shift register mechanization of the tradeoff study fits quite nicely in this system.

The dual galvanometer optical scanning system described in paragraph 2.8 of this report is assumed for this mechanization.

Figure 2-12 depicts the timing sequence.

ASSUMED SYSTEM B CHARACTERISTICS

. Picture Bits:	53152 (176 x 302)
. Frame Rate:	30 fps
. Interlace:	2:1
. # of Detectors:	88
. Horizontal Frame Time:	16.67 milliseconds
. Number of Detector Scan Samples:	302
. Scan Pattern:	Bidirectional
. Scan Duty Cycle:	95%
. Number of Vertical Lines:	302
. Vertical Line Time:	$\frac{(16.67)\ (.95) \times 10^{-3}}{302} = 52.43\ \mu s$
	Active 80% = 41.94 µs
	Retrace 20% = 10.49 µs
. Sample Time per Detector:	$\frac{41.94 \times 10^{-6}}{88} = 0.477\ \mu s$
. Sample Rate:	2.1 MHZ
. Memory Rate:	176 x 302 = 53152 bits per shade of grey
. Total Memory for 16 shades of grey	212,608 bits per display ([illegible],?92 bits in nearest binary [illegible]figuration)

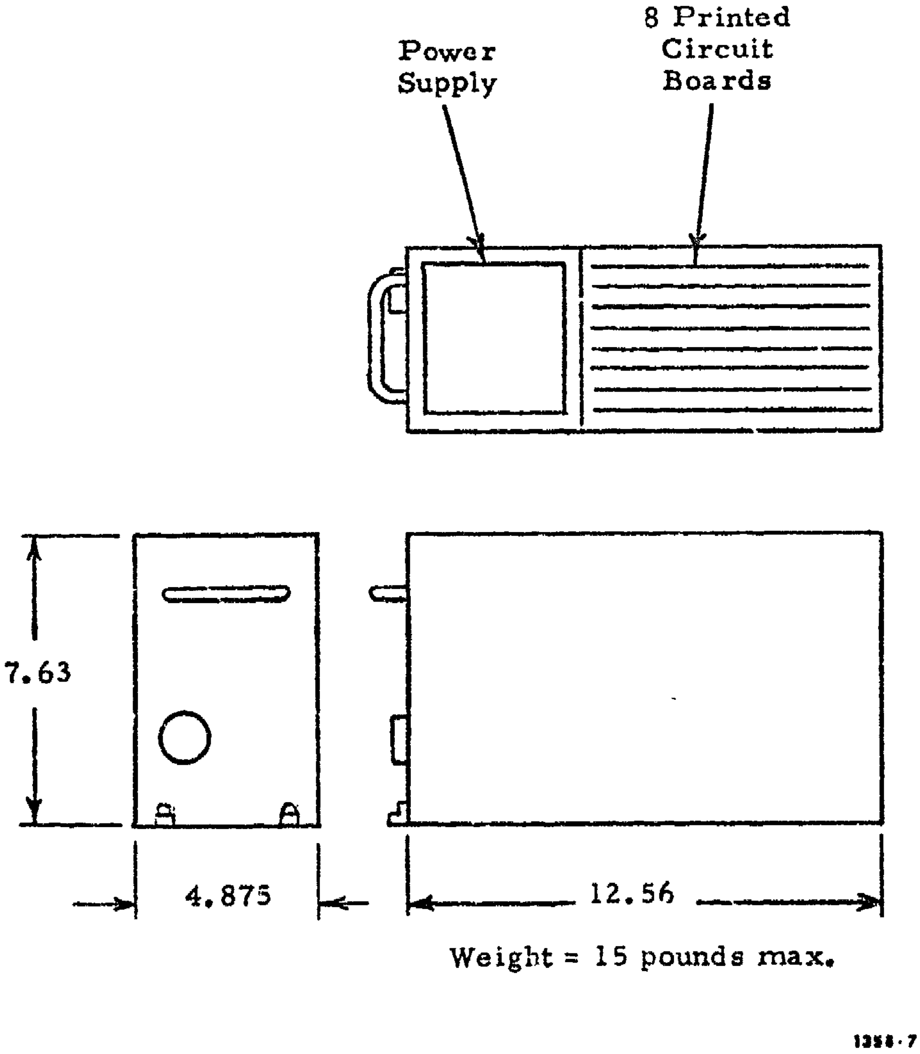
The display monitors can be standard TV displays or 302 line, vertical scan, patterned rasters. Interlace will be 2:1 in the vertical dimension, i.e., detector interlace, as provided by the optical system and as compensated for in the sweep generator.

System B in a 16 shade of gray configuration can be packaged as a single 1 ATR short unit (10.125" w x 7.62" h x 12.56"l) with a weight of 25 pounds maximum, or it could be split into 2 units. The two units would each be 1/2 ATR short with a weight of 14.5 pounds each. Figure 3-13 depicts the 1/2 ATR configuration. The system power requirements would be less than 160 watts.

3.6.3 System C

Considering a more complex hypothetical system C, it is possible to extrapolate from System B previously described. Again, the scan sequence allows the use of a shift register memory. The scanning sequence of the dual galvanometer optical system of paragraph 2.8 is assumed. Assumed key parameters include:

. Picture Bits:	212608 (352 x 604)
. Frame Rate:	30 frames per second
. Interlace:	2:1
. Number of Detectors:	176
. Horiz. Field Time:	16.67 μs
. Horiz. Frame Time:	33.33 μs
. Number of Detectors Scan Samples:	604
. Scan Pattern:	Bidirectional
. Scan Duty Cycle:	0.95
. Number of Vertical Lines:	604
. Vertical Line Time:	$\frac{(16.67)\ (0.95) \times 10^{-3}\ \text{sec}}{604} = 26.22\ \mu s$



Display Processor, Single Channel, System B

Figure 3-13

SYSTEM C Continued

Active = 80% = 20.97 μs

Retrace = 20% = 5.25 μs

Sample Time per Detector = $\frac{20.97}{176}$ μs = 0.119 μs

Sampling Rate: 8.4 MHz

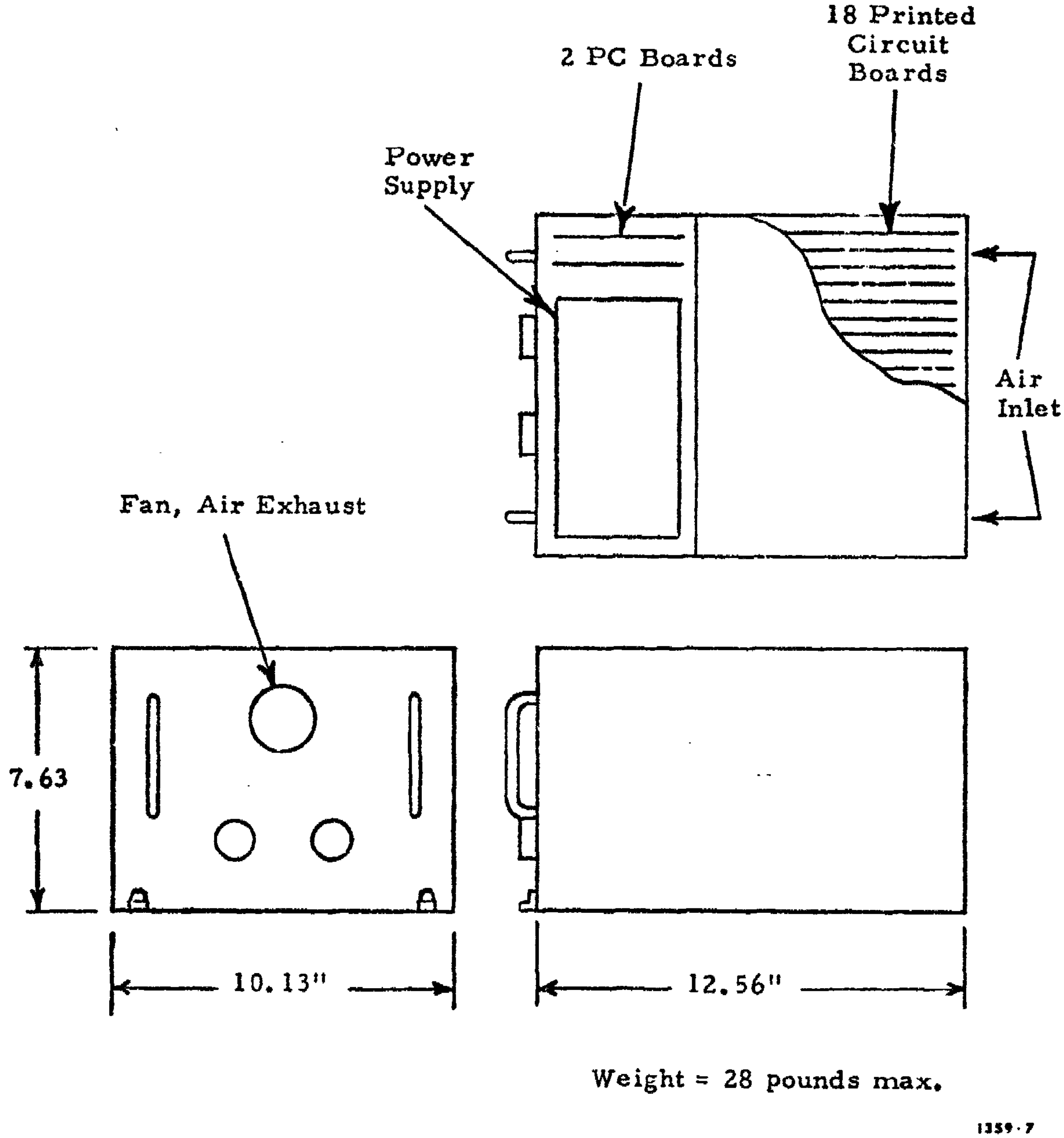
Memory Size: 352 x 604 = 212,608 bits per shade of gray

Total Memory for 16 shades of gray = 850,432 bits per display

The display monitors can be standard TV displays or special 604 line, vertical scan, patterned rasters. Interlace will be 2:1 in the vertical dimension, i.e., detector interlace.

System C memory can be packaged as two 1 ATR short units (10.125"w x 7.63"h x 12.56"l) with a weight of 28 pounds each (56 pounds total), or a single unit of 10.125"w x 7.63"h x 22'l with a weight of 54 pounds is feasible. Figure 3-14 depicts the 1ATR configuration. Total system power requirements would be 500 watts.

The memory configurationsof Systems B and C are related in a modular fashion such that if a System B memory is defined as a module, then four such modules can be interconnected without internal modification, and will become a System C memory. Suitable high speed multiplexers as well as analog-to-digital and digital-to-analog converters are of course required.



Display Processor, Single Channel, System C

Figure 3-14

4.0 FURTHER DEVELOPMENT OF IRMX CONCEPT

4.1 GENERAL

The investigation into dual field optical multiplexing has so far only addressed itself to a general comparison of possible methods. This section will discuss the transition from theoretical concepts to actual hardware. The feasibility of dual field multiplexing has been shown; however, in order to determine the practicality of this concept, it would appear desirable to evaluate actual, implemented hardware. This particularly applies here since the system output is a visual presentation and since display effects due to variations in frame rate, resolution, quantized video, etc. are most easily evaluated by actual visual observation instead of theoretical prediction.

It was previously stated that dual Infrared Image Multiplexing presents two separate, yet related problems, namely the optical scanning and multiplexing of the two images and electronic processing of the two images.

A logical progression leading to the eventual development of a high performance, multiplexed IR display system would first be the laboratory evaluation of the electronic image processing and multiplexing concept and then, if this proves promising, the development of an efficient optical multiplexing scanner.

Two existing IR display systems which could readily be adapted for such an evaluation are the AN/PAS-7 Hand Held Thermal Viewer (HHTV) and the Multi-purpose Infrared System (MIRS).

The following paragraphs describe how either one of these systems can be utilized for a laboratory evaluation of the IRMX concept.

4.2 DUAL FIELD OF VIEW HHTV

4.2.1 Basic HHTV Operation

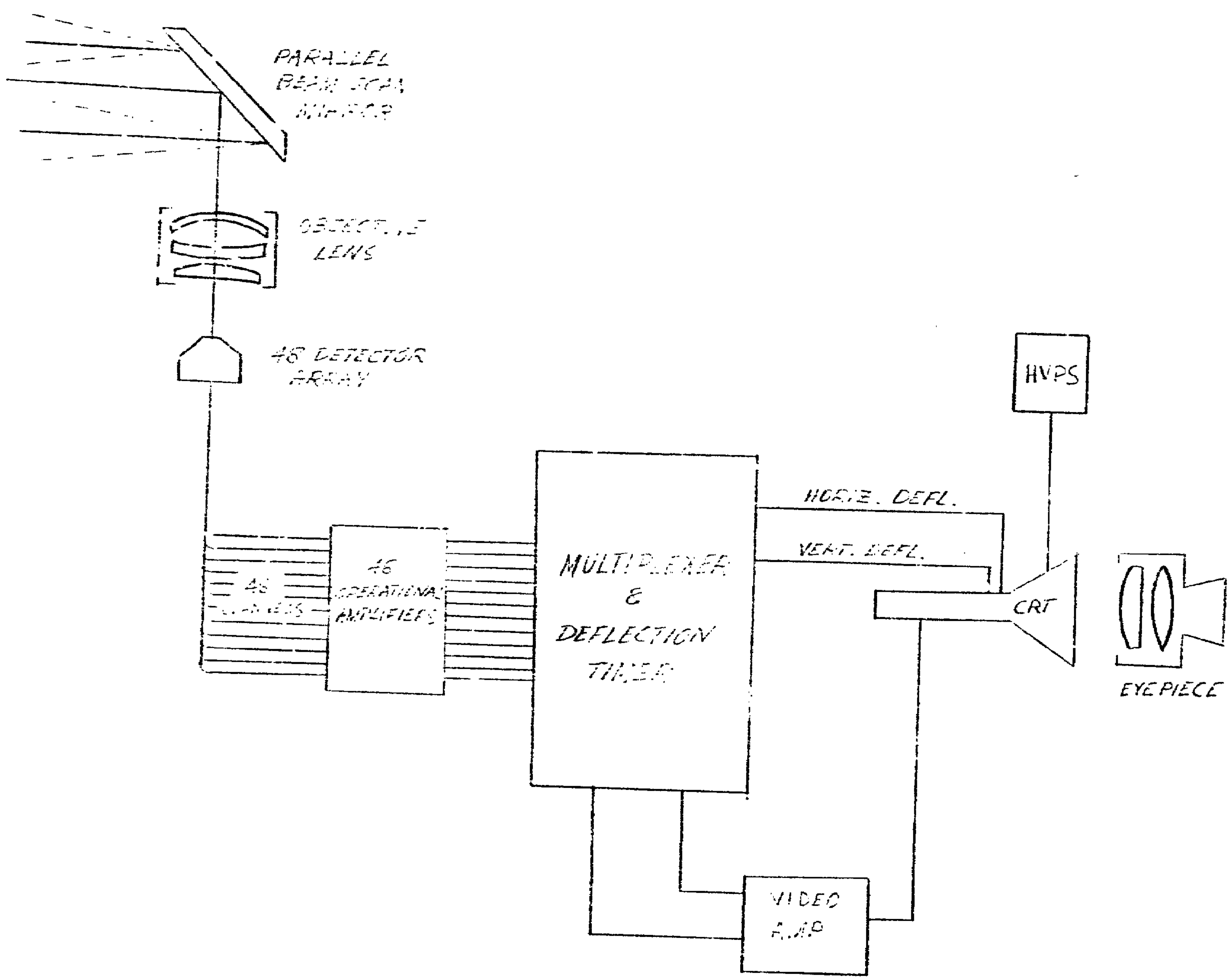
The AN/PAS-7 Viewer is a Hand-Held Thermal Viewer. Figure 4-1 shows the basic functional block diagram. A parallel beam scan mirror oscillating through $\pm 3^{\circ}$ directs the to be viewed image through an objective lens to the 48 element vertical IR detector array. The detector outputs are amplified by 48 operational amplifiers and then multiplexed with appropriate timing and deflection waveforms to present a 48(H) x 156(W) element raster on the cathode ray tube. The cathode ray tube display is viewed through an eyepiece magnifier. The scan mirror operates at a 15 Hz frequency which results in a 15 Hz CRT field update rate. The total scanned field is 6° in elevation by 12° in azimuth.

4.2.2 Optical Multiplexer for HHTV

The optical dual image scanner for the HHTV can be a very simple device. It can consist of a rotating 12 inch. diameter disc located in front of the HHTV aperatus at 45° with respect to the viewer field of view. One half of the disc can be mirrored and the other half can be transparent or open, (see Figure 4-2). The disc is driven at constant speed by a DC Motor-Gearhead assembly. During each revolution of the disc the HHTV scanner alternately sees the "straight ahead" field of view and a second field of view at 90° to the first FOV.

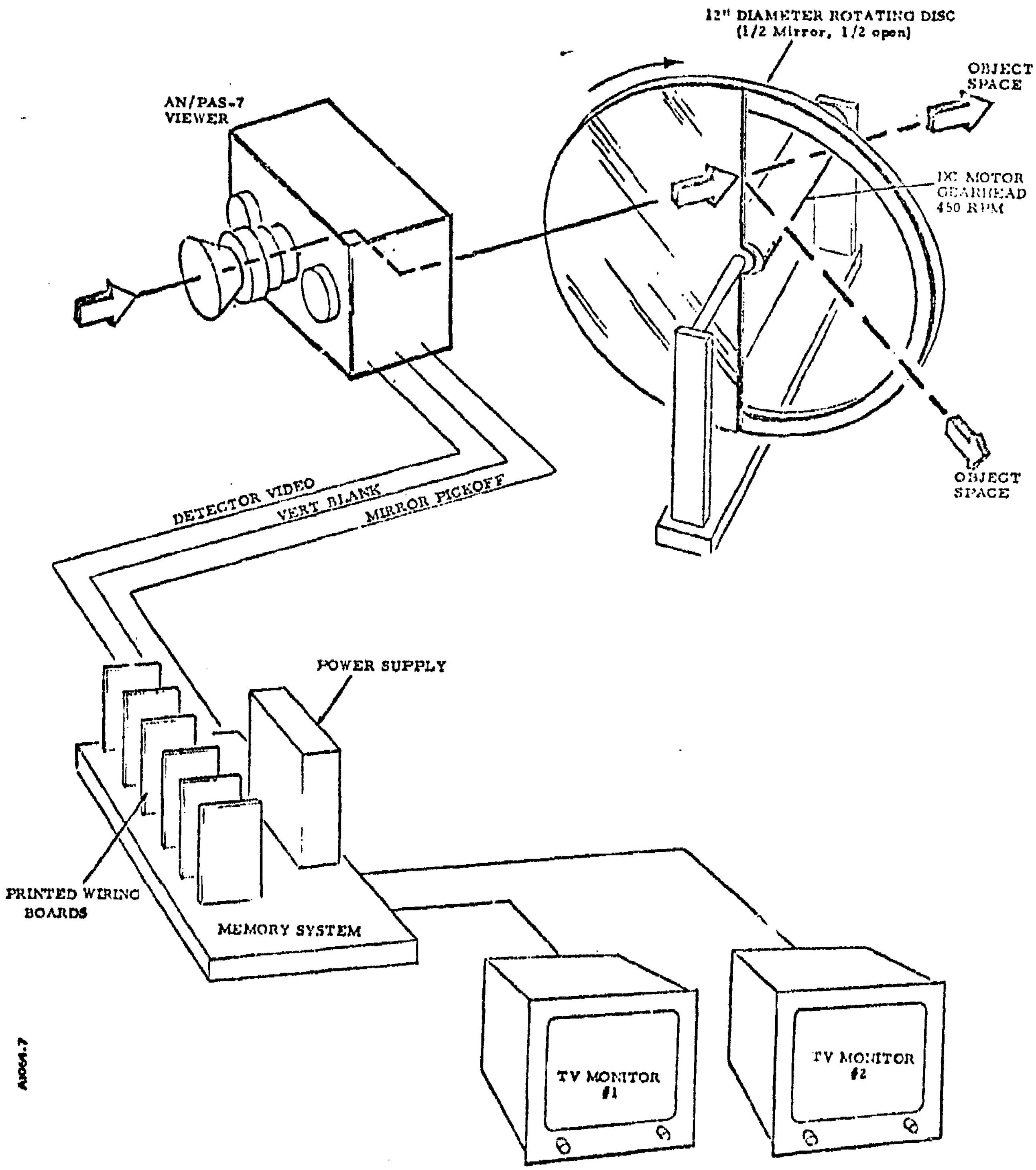
The existing Flip-Flop mirror scanner operates at 15 frames per second. In the Dual Image mode it will scan 7.5 frames per second per FOV. This requires a corresponding disc revolution of 7.5 RPS, i.e., 450 RPM.

The 12 inch diameter disc size is chosen based on the fact that due to the breadboard configuration of the total system a compact, highly efficient and costly scanner is not warranted. The relatively large disc size should not impose a penalty in the laboratory environment.



FUNCTIONAL BLOCK DIAGRAM, AN/PAS-7 HAND HELD THERMAL VIEWER

Figure 4-1



HHTV Modified for Dual Image Scanning

Figure 4-2

A calculation of scanning efficiency of the rotating disc method shows that with the 12 inch diameter disc, full aperature coverage occurs for 115° per 180° of rotation. The basic HHTV displays 156 Horizontal elements per scan. In the Dual Image Mode a minimum of 100 Horizontal elements per field will be retained. This should be satisfactory for a breadboard evaluation of Dual Image Multiplexing, particularly since the total field can be scanned by adjustment of the sync phasing between viewer mirror and dual image scanner.

The revolving dual image scanner and flip-flop viewer mirror must be correctly phased in order to properly perform the dual image scanning function. In a practical application this would require that the revolving disc drive be synchronized to the flip-flop mirror pickoff. However, in keeping with a low cost approach, the free running disc drive can be manually synchronized to the flip-flop mirror by rotation and locking of the motor-gearhead assembly. Manual synchronization will be required each time the system is energized. However, this is much less complex and costly than an electronically phased mechanism.

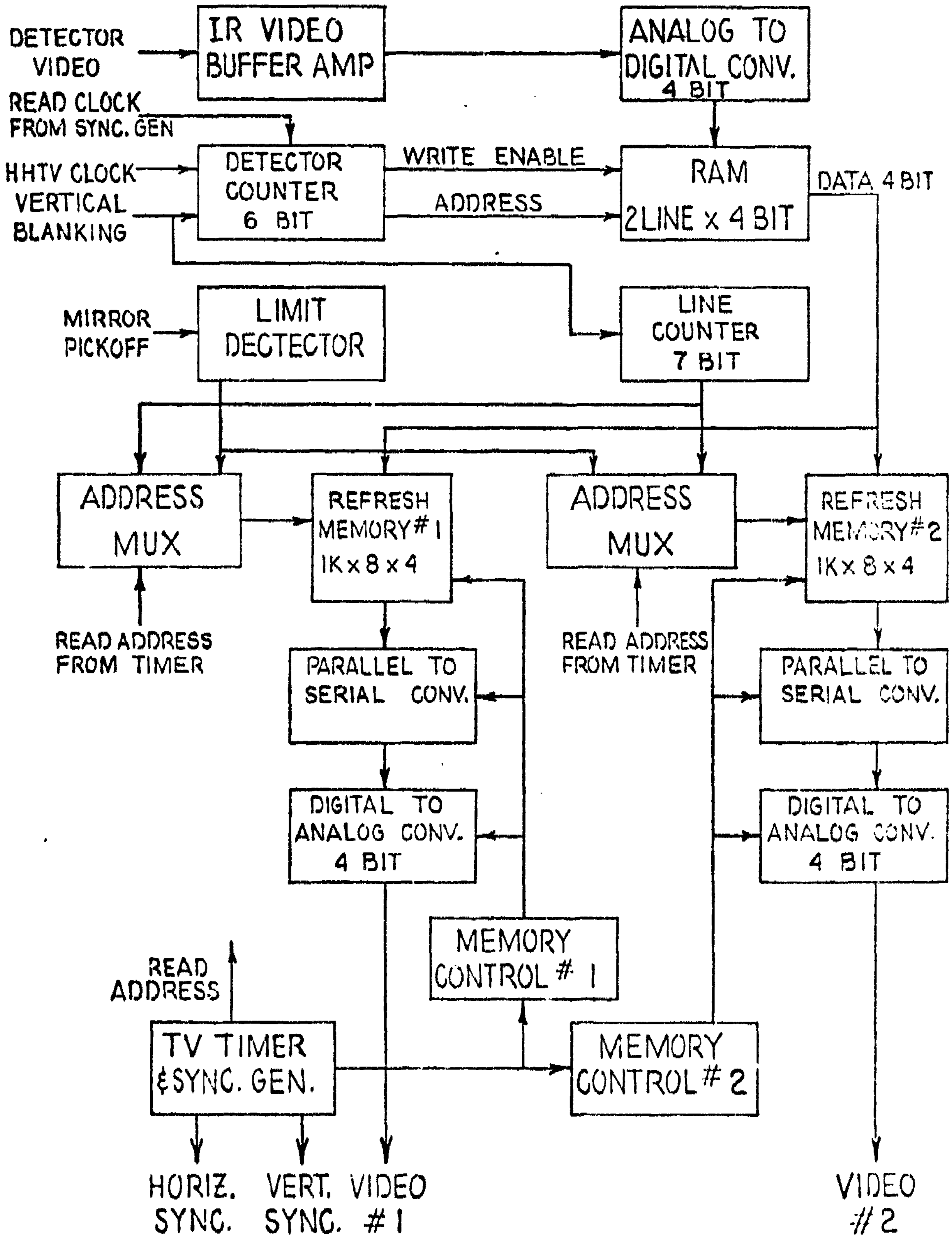
4.2.3 HHTV Dual Image Processor

A mechanization for electronic HHTV dual image processing was described in paragraph 3.6.1. An alternate configuration, recommended for breadboard evaluation, is shown in block diagram form in Figure 4-3.

In this configuration, the existing HHTV CRT and sweep circuits would not be used. Instead, the HHTV detector video would be A/D converted and routed through a Memory System to two standard, 525 line TV monitors. In addition to HHTV detector video, HHTV Clock, Vertical Blanking and Mirror Pickoff Signal are required to drive the Memory System.

Primary advantages of this mechanization are:

- Improved display via increased refresh rate
- Compatible with standard display for multimode applications
- More suited to image enhancement techniques
- Signals compatible with video recording systems



HHTV MEMORY SYSTEM

Figure 4-3

The configuration includes:

- o Signal processing and conversion at existing HHTV rates and formats for writing data into memory.
- o Solid state refresh memory
- o Memory controller and standard TV timing generator
- o Memory readout in standard TV format, i.e., 60 Hz refresh, 2:1 interlace, 525 line
- o Digital to analog conversion for application to standard TV display monitor
- o Frame Freeze independently on one or both display
- o Increased refresh rate to provide reduced display flicker and thus improved display viewability

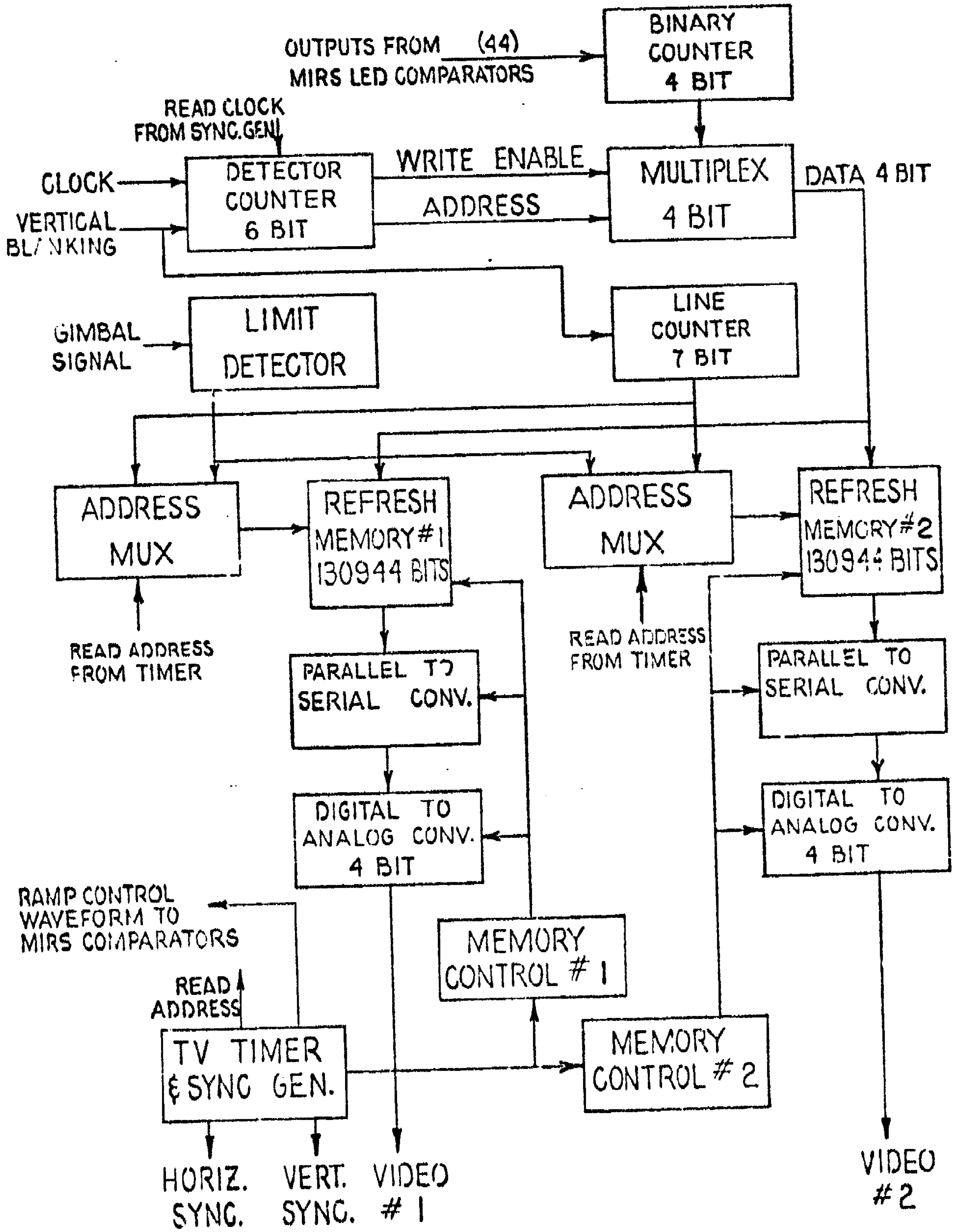
4.3 DUAL FIELD OF VIEW MIRS

4.3.1 Optical MIRS Multiplexer

The MIRS is a more sophisticated IR viewer than the LHTV and, due to its higher resolution and thermal sensitivity, represents a better choice for breadboard evaluation. A performance comparison of the single mode and multiplexed mode display should yield more precise results since it should be easier to detect small variations in display quality in the MIRS. In order to avoid a costly optics and scanner development it is recommended that the optical multiplexer for the MIRS be the same rotating disc image splitter as was recommended for the HHTV (Figure 4-2).

4.3.2 MIRS Dual Image Processor

A recommended configuration for a MIRS mechanization is shown in Figure 4-4 and would be similar to the above described HHTV system in that video signals would be digitized, stored in a solid state refresh memory, and read out in standard 525 line TV format.



MIRS MEMORY SYSTEM

Figure 4-4

The advantages of improved display refresh via reduced flicker, TV compatibility for displays and video recorders, and image enhancement adaptability are all inherent to the MIRS as well as the HHTV configuration.

The system elements would be as cited for the HHTV mechanization. Basic differences exist in memory size and analog to digital converter mechanization.

The interface between the MIRS and the memory system would be via the video signals currently driving the MIRS LED array and the mirror position or limit signals. The cusp control waveform driving the LED Driver Stage comparators will be replaced with a linear ramp and each of the LED drive signals, which are a time related function of brightness, or grey level, will be used to control a 4 bit counter. Thus the analog to digital conversion comprises a simple ramp mechanization.

The memory size will be 88 x 372 x 4 or 130,944 bits per display. This is four times the size of the HHTV memory and includes double the resolution in both azimuth and elevation.

A possible problem exists in the azimuth position and lateral repeatability if the mirror motion is not symmetrical in terms of velocity and turn around/ start up times. This can be overcome by providing a suitable mirror position element mounted to the mirror assembly and used to develop a mirror position signal for control of azimuth location of data in memory.

4.4 DUAL IMAGE OPTICAL SCANNER

The Dual Image Optical Scanner previously recommended for breadboard evaluation of a multiplexed HHTV or MIRS is very simple, has a low scan efficiency and will be inexpensive to fabricate. For a breadboard evaluation, in a laboratory environment it should prove quite adequate; however, it would be unacceptable for a high performance, airborne IR display system.

The development of a high performance Dual Image Optical Scanner should be predicated on the results of the breadboard evaluation of the multiplexed HHTV or MIRS. The recommended approach is to then develop a Collimated Double Galvo Scanner, based on the principle described in paragraph 2.8. Since the development cost undoubtedly will be appreciable, precise design constraints with respect to field of view, optical speed, scan efficiency and physical size should be determined so that the resultant design can be utilized in a functional application.